Getbol, Korean Tidal Flat

For Inscription on the World Heritage List

Republic of Korea

Section 2

Description

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Description

2.a Description of Property

Tidal flats are sandy to muddy or marshy flats in the intertidal zone that are emergent during low tide and submerging during high tide. In general, they include the subtidal zone which is the area influenced by tidal current below the low-water line, and supratidal zone which is the area above the high-water line but sometimes under water during extremely high tides and storms. The sediments, affected by daily tidal currents, are transported toward the shore from the ocean. Sand particles are deposited on the lower part of the flats, whereas finer sediments accumulate on the upper part closer to the shore. Different types of tidal flats formed by this sedimentation provide various habitats for many living organisms and create an important coastal ecosystem.

Getbol, a word of native Korean origin, means tidal flats. This word in a narrow sense refers to an intertidal zone. Its meaning or use is, however, often extended to include supratidal, intertidal and subtidal zones. Tidal channels, tidal beaches and salt marshes are also considered as a part of Getbol as they are influenced by tides.

The nominated property, the 'Getbol, Korean Tidal Flat' has distinctive features when compared to common coastal tidal flats elsewhere. The property is formed by terrigenous sediments that are deposited around the numerous bedrock islands along the rocky coast. The term 'Getbol' used in this nomination dossier refers to the characteristic tidal flats formed around the islands including some bays and estuaries along the southwest coast of Republic of Korea (ROK).

The nominated property abuts the shores of the Korean Peninsula in the southeastern part of the Yellow Sea, which is located in the northwest of the Pacific Ocean. It is an outstanding representative system to conserve the coastal ongoing geological processes induced by unique geological systems combined with special oceanographic and climatic conditions. It also is an outstanding example of an ecosystem closely interrelated with the geological processes, being characterized by a variety of habitats. The geodiversity and biodiversity provide us with important ecosystem services for human society.

2.a.i The Yellow Sea

The Yellow Sea, similar to the Black Sea, the Red Sea and the White Sea, takes its name from its water color. Land-derived suspended sediments color the waters yellow. Located in the northwest of the Pacific Ocean, the Yellow Sea is situated on the margin of the Eurasian Plate. This sea, surrounded by ROK, DPRK, and China, is a submerged part of the huge Asian continent that has become a shallow sea due to sea level rise after the Last Glacial Maximum. With the Holocene sea level rise, this land area was transformed into a shallow sea just like the Persian Gulf and the Sunda Shelf and became one of the few remaining epicontinental seas. The Yellow Sea has an average depth of 44 m (the deepest part being 103 m). It has a vast and flat seafloor surface: The eastern side, neighboring the Korean Peninsula, is deeper and has a more rugged base than the western side close to China. Post-glacial sea level rise, which increased rapidly after the Last Glacial Maximum, began to slow down from about 9,000 yr BP and thus tidal flats began to form along the shores.

The Yellow Sea is characterized by a variety of tidal ranges. Tidal waves originating from the Pacific Ocean enter the Yellow Sea and move counterclockwise, pushing against the gently-shelving shores on the east. As a result, ROK's west coasts on the eastern side of the Yellow Sea all have macrotidal ranges (3.5-10 m), whereas all the Chinese coasts experience microtidal (<2 m) or mesotidal ranges (2-3.5 m). The tidal flats in the Yellow Sea region are supplied with the world's largest volumes of terrigenous sediments. Situated next to the eastern part of the gigantic Asian continent, the Yellow Sea presents a coastal environment with distinct seasonal changes due to the strong continental monsoon climate. Huge amounts of sediments come from the Yellow and Yangtze rivers in China as well as from Yalu, Daedonggang, Hangang, Geumgang and Yeongsangang rivers on the Korean Peninsula. The sediments discharged are redistributed around the shores by tides and waves generating vast mud and sand flats around the edge of the Yellow Sea.

Thanks to the large amounts of nutrients supplied by the rivers, primary production in the Yellow Sea is more than double that of the world's oceans. This high primary production in the nominated property has provided diverse invertebrates and fish with well-established habitats. These tidal flats are also a vital stopover site for over ten million migratory birds traveling from the breeding grounds in Siberia and Alaska to the overwintering grounds in Australia and New Zealand during austral summers. In particular, the Yellow Sea hosts the world's highest ratio of endangered migratory bird species along the East Asian-Australasian Flyway (EAAF), the most vulnerable route among the three main global flyways. More than 30% of the total population of 25 shorebirds and plover species traveling to and from their breeding grounds use the Yellow Sea tidal flats as a stopover site. Among these birds, the population of 15 species, which include the great knot (*Calidris tenuirostris*), essentially rely on the Yellow Sea tidal flats for their survival. Above all, the Yellow Sea tidal flats are the last refuge for spoon-billed sandpipers (*Eurynorhynchus pygmeus*). There are only 300 to 600 sandpipers left in the world. These waterbirds have been

decreasing in number due to human influence. Therefore, the area is receiving much attention from around the world, including the IUCN.

The rich biodiversity found in the nominated property plays an important role not only for the living organisms in the tidal flats, but also for us humans. Humans have been living near the tidal flats for thousands of years, using them as necessary food resources. Traditional fishing activities based on indigenous knowledge have become a part of the tidal flat ecosystem itself. The property has kept alive traditional fishing techniques, and thus all human activities have a direct lineage from ancient times to the present day and will continue to be practiced into the future.

At World Conservation Congresses in 2012 and 2016, the IUCN adopted resolutions 5.028 and 6.026 emphasizing, respectively, the importance of the Yellow Sea region intertidal zone and the urgent need for its protection. The nominated property, located on the southeastern side of the Yellow Sea, is an intertidal zone with thousands of islands. The property displays very different geological features and diverse biological processes compared to those found on the western and northern sides of the Yellow Sea, which are characterized by open-coast and deltaic-estuarine environments. This clearly shows that the property makes a distinct and unique contribution to the geodiversity and biodiversity of the Yellow Sea, as well as assisting in its conservation.

The three countries surrounding the Yellow Sea have been making efforts to protect the Yellow Sea's natural environment. With the inscription of the nominated property as a UNESCO World Natural Heritage site, the Yellow Sea region will play a very important role in conservation of the natural heritage that is dear to all humankind.

Figure 2-1. Representative scenery of the inner part of rocky island-type (archipelagic) mud flat in the nominated property (Shinan Getbol)

2.a.ii Physical Setting

2.a.ii.1 Tectonics and Geomorphology

• Formation of Archipelagic Coast

The tectonic framework of East Asia in general, including the Korean Peninsula, can be characterized by two major factors: the northwestward-directed subduction of oceanic crust beneath the Japanese Island Arcs and the eastward expulsion of continental crust by the collision of the Indian and Eurasian plates. The Korean Peninsula has experienced a complex tectonic history, although it now stands in a tectonically less active region at the margin of the stable, eastward-pushed continental crust. During the Paleozoic Era, the small and independent continents, located near the equator but not far away from the Gondwana Supercontinent, gradually moved to the north. They then collided and merged with the Laurentian Supercontinent during the Mesozoic Period to attain their present shape and position.

During these tectonic movements, the Yellow Sea region, including the Korean Peninsula and southeastern China, merged (obducted) as part of the same continent on the margin of the Eurasian Plate. Subsequently, as the Pacific Plate continued to subduct to the west, the southern region of ROK as well as the Yellow Sea area were influenced by severe tectonic movements and volcanic activities in various forms during the Jurassic to Cretaceous periods. In some areas, plutonic rocks were intruded.

The northeast-southwest tectonic structure of sedimentary basins on the Korean Peninsula and the Yellow Sea is attributable to the relative movement of the Eurasian and Pacific Plates. The Korean Peninsula, being located closer to the subduction zone than China, witnessed the uplift of many uplands induced by active tectonic movements and intrusion of plutonic rocks since the Jurassic Period. Explosive volcanic activities were widespread in the southern part of the peninsula during the Cretaceous Period. These are why the Peninsula and its western coastal area show very irregular landforms with high topographic relief. Thus the movement of the two plates has also influenced the formation of the coastal geomorphology of the sedimentary basins.

With the long period through the Quaternary of alternating glacial and interglacial cycles, repeated sea level rise and fall has resulted in submergence and emergence of the area. Different styles and rates of erosion and weathering occurred during these episodes, with rugged relief being developed across the area during times of low sea level. Since the Last Glacial Maximum, sea level rise has resulted in submergence of the lower parts of the Yellow Sea, transforming the more rugged and hilly eastern regions of the Yellow Sea into islands. Consequently, the southeast coasts of the Yellow Sea (or the southwest coasts of the Korean Peninsula) evolved into an archipelagic coastal region with over 3,000 rocky islands and complex coastlines. The nominated property includes more than 900 islands, between which are vast areas of tidal flats. The height

of the rocky islands is mostly under 100 m, but some islands reach 300 m. The outer islands of the archipelago dampen ocean waves and disperse their energy, and so prevent the tidal flat sediments from being washed out to the sea. This results in a stable region of tidal flats within the protected inner area of the archipelago.

Because of the tectonic movements and the high rate of sedimentation in the western Yellow Sea, the deepest parts are found on the eastern side. The terrigenous sediments coming from the Yellow and Yangtze rivers in China become widely dispersed upon reaching the sea, and the western side of the Yellow Sea therefore displays a relatively gentle seafloor topography. On the ROK's side, by contrast, terrigenous sediments supplied by Hangang and Geumgang rivers are transported southwards by strong coastal currents. These flows have generated the north-to-south-oriented shallow marine and coastal sedimentary deposits with a relatively steep sea-floor topography.

Figure 2-2. Bathymetry and distribution of surface sediments in the Yellow Sea and the northern part of East China Sea (after Koh and Khim, 2014)

• Sea Level Rise and Formation of Tidal Flats

Sea level during the Last Glacial Maximum was approximately 130 m lower than the present and it began to rise towards its present level from about 20,000 years ago in the southern part of the Yellow Sea. Sea waters flooded the continental shelf of the South China Sea and eventually also the Yellow Sea. It was only 14,000 years ago that the Yellow Sea became a sea. It is suggested that the sea level around the Yellow Sea shows a step-like rising pattern of submergence (Figure 2-3). The sea level rose rapidly until about 9,000 years ago, to reach the level of 15 to 20 m lower than the present. From then onward, the rate of sea level rise decelerated and the modern coastline became defined some 4,000-6,000 years ago.

The Yellow Sea is largely a shallow and wide gulf, the shorelines of which are lined by extensive tidal flats produced in the course of the Holocene sea level rise. The slowing down of sea level rise about 9,000 years ago also resulted in the reduction of capacitive (accommodation) space in the Yellow Sea basin (Figure 2-4). As a consequence, terrigenous sediments began to accumulate along the shores to produce the modern tidal flats.

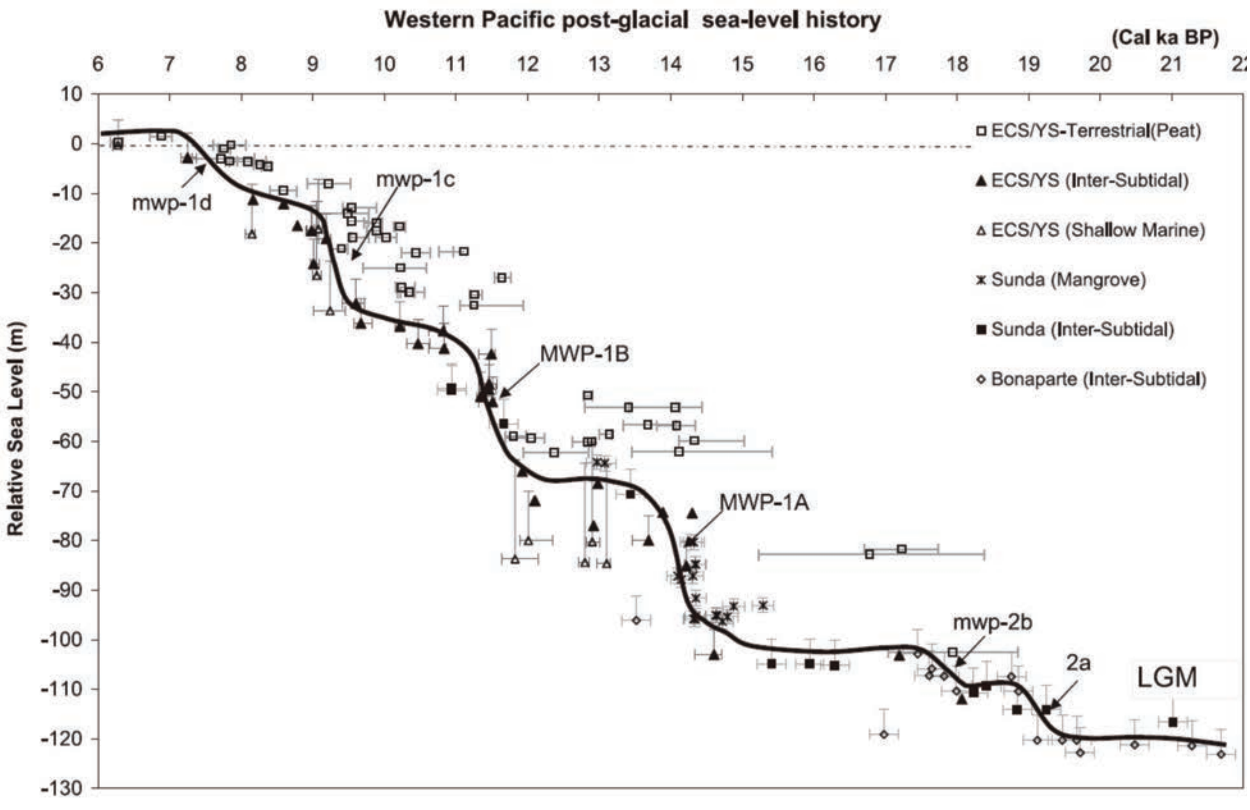


Figure 2-3. The Holocene sea level rise after the Last Glacial Maximum in the region of the Yellow Sea (Liu et al., 2004)

Large-scale tidal flats along the coasts of the Atlantic Ocean, including those of the Wadden Sea in Germany-Netherlands-Denmark and Georgia Coast in U.S.A. have been formed in general from offshore sediments, carried by tidal currents towards coastal areas with recent sea level rise. The sediments have been supplied and redistributed mostly from Quaternary glacial deposits, although there has also been a contribution by rivers, such as the Rhine.

The tidal flats along the west coast of the Korean Peninsula have been formed by the accretion of terrigenous sediments supplied by the Peninsula's rivers in the course of their dispersal by tidal flat currents, wave action and wind-driven longshore currents. As a result, vast tidal flats have developed along the southwest coast, with even wider tidal flats forming around the estuary of large rivers and the island coasts. The open coasts, estuaries and bays of ROK's southwest coast mostly display the characteristics of the archipelagic and/or rias coast and thus wide tidal flats have developed close to the islands.

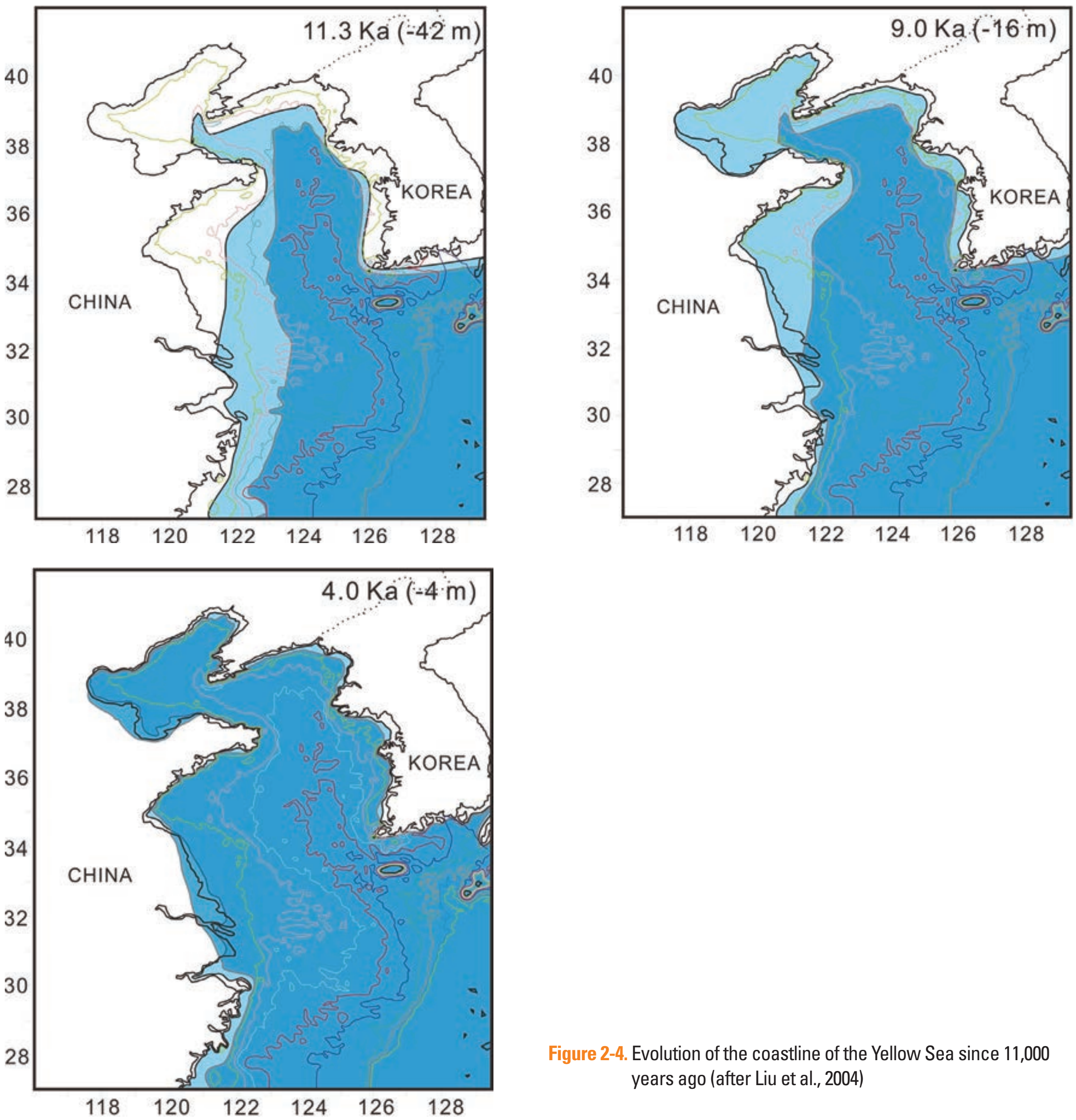


Figure 2-4. Evolution of the coastline of the Yellow Sea since 11,000 years ago (after Liu et al., 2004)

2.a.ii.2 Hydrology

• Oceanic Currents

The North Equatorial Current turns to the north near the Philippines in the western Pacific Ocean and evolves into the Kuroshio Current as it moves along Taiwan and Japan. This current soon diverges into two streams: the Yellow Sea Warm Current, which enters the Yellow Sea through the southern sea of the Korean Jeju Island, and the Tsushima Warm Current, which flows through the waters between ROK and Japan to arrive at the East Sea. The Yellow Sea Warm Current even forms a longshore current in winter near China until it reaches Bohai Bay.

Those currents that affect the west coast of ROK change their flow patterns with the season (Figure 2-5). In winter, cold water from Bohai Bay moves down to the south and strong northwesterly winds change it into the powerful West Korea Coastal Current. In summer, waters discharged from the Yangtze River are sometimes pushed by the southeast monsoon to become the Yellow Sea Warm Current towards the west coast of ROK. A longshore current is then formed and moves up along the west coast of ROK. This seasonal change of the West Korea Coastal Current plays an essential role in containing suspended sediments that contribute to the extensive mud flats in the nominated property.

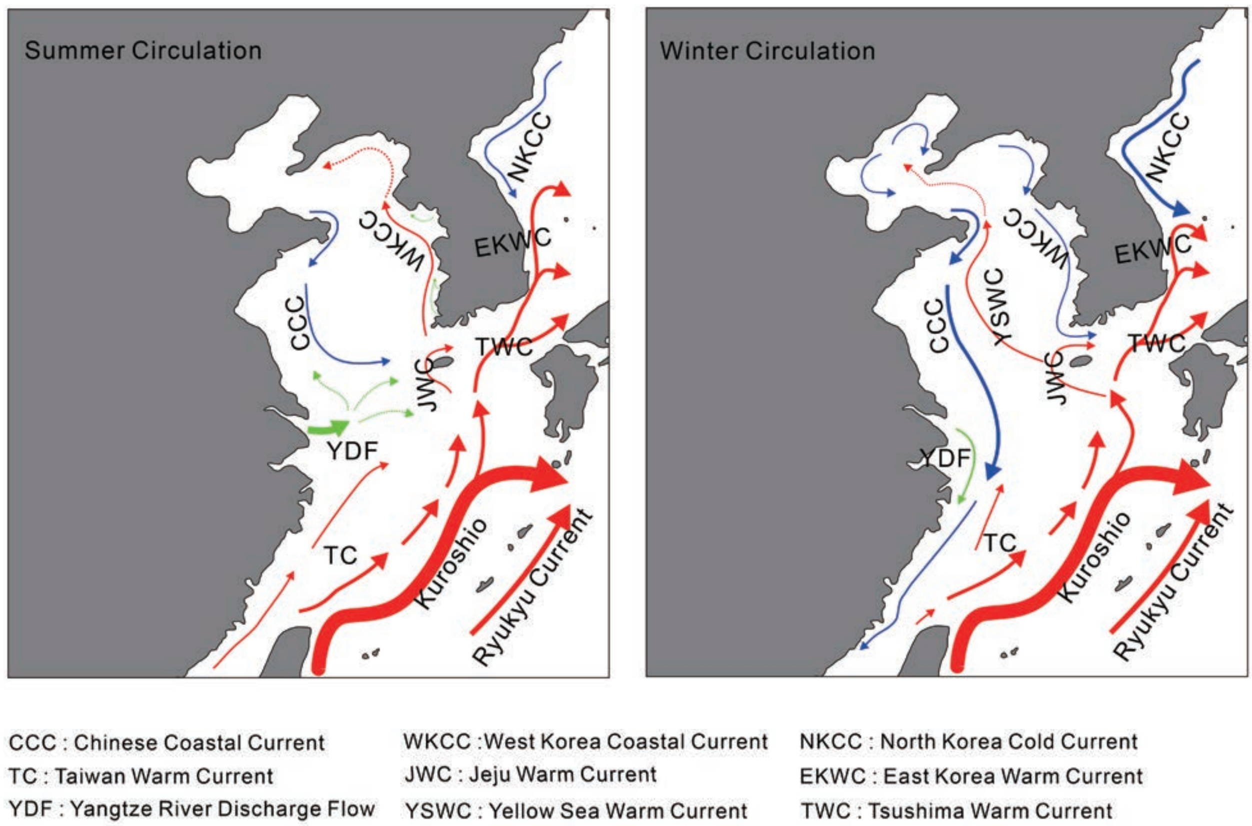


Figure 2-5. Schematic diagram illustrating major current systems in the Yellow and East China seas and the adjacent areas (after Guan, 2004)

• Tides and Waves

Tidal-wave shoals from the Pacific Ocean traverse the entrance of the Yellow Sea and a shallow continental shelf and run to the northwest. Rotating counterclockwise, they then form a tidal system with four amphidromic points in the inner part of the Yellow Sea (Figure 2-6). With zero amplitude between the tidal rise and fall, an amphidromic point serves as an axis of rotation for tidal waves. The points in the Yellow Sea are tilted towards the west. For these reasons, most of the coastal areas in China have mesotidal ranges of less than 3.0 m, whereas the ROK's coastal region shows a macrotidal range of more than 4.0 m. The tidal range even reaches up to 10 m around the estuary of Hangang River. The coasts near the nominated property are all macrotidal with ranges between 3.5 to 6.8 m. The tides in the property are semidiurnal with two tides that create two high and two low tides a day in N-S to NW-SE cycle. The macrotidal conditions in and around the islands have a significant influence on tidal flat sedimentation. The tidal flats surrounding individual islands are separated by deep channels in which the strong tidal currents change direction every 6 hours. In areas where the distance between islands are wide or where the island is connected to the Korean Peninsula, very wide tidal flats are created.

Co-tidal Chart (M2)

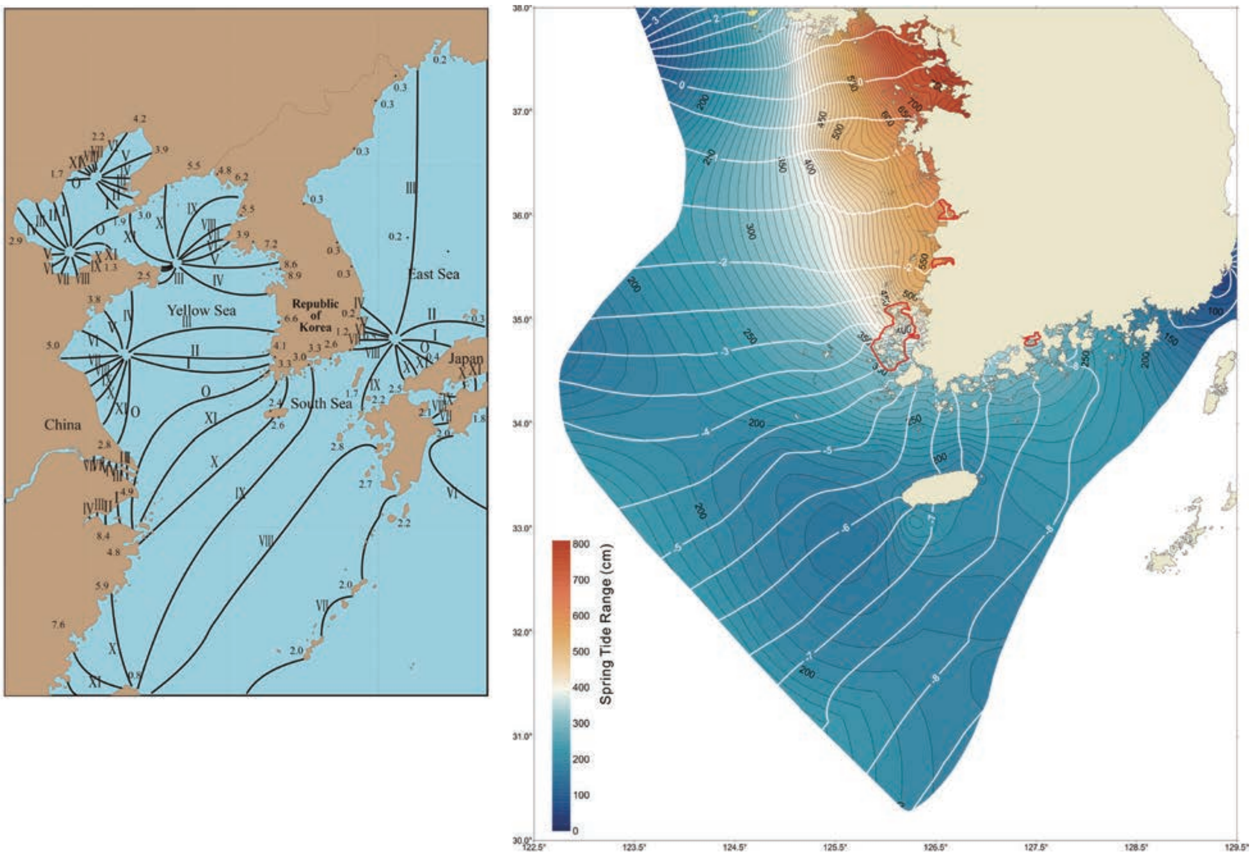


Figure 2-6. Co-tidal chart (M2 tide only) in the Yellow Sea and spring tidal range on the southwestern coast of ROK (after Guo and Yanagi, 1998; Kang et al., 2002)

Being located in the eastern parts of the Yellow Sea, the property is greatly influenced by the continental-monsoon-driven seasonal change of wind waves. The height of waves reaches generally 3 to 5 ㎙ in winter in the open seas of the property and lowers to 1 to 2 ㎙ in summer. Yet, the inland seas of the property experience only small waves with height no greater than 50 ㎝ regardless of the season.

• Cold Water Mass

The seasonal Yellow Sea Cold Watermass forms in the bottom layers in the middle part of the Yellow Sea from April to November. When compared to nearby waters, these waters have lower temperatures and are highly saline. Its distribution and scale changes with the seasons. In fact, this cold watermass is formed when the chilled coastal waters of Bohai Bay sink below the surface in winter. Due to the Yellow Sea Cold Watermass, the sediments discharged from major ROK's rivers or others delivered by the West Korea Coastal Current are not washed away to the open sea. As a result, the property maintains a stable sediment supply system.

2.a.ii.3 Climate

• Continental Monsoon Climate

Being in a warm and humid continental temperate climate zone (Dfa), the nominated property is hot and rainy in summer and cold and dry in winter. With four clearly distinct seasons throughout the year, the property is generally humid and shows a big difference in temperature between summer and winter months. The property is dominantly influenced by the ocean in summer and by continent in the winter, as it is strongly affected by East Asian continental monsoon climate (Figure 2-7).

The presence of a continental monsoon climate is strong across the entire Yellow Sea. Hence, strong northwesterly winds blow during winter time and these turn to the weak southeasterly winds in summer. When the winter comes, the dominant northwesterly wind travels longer distances southeast across the Yellow Sea. With longer fetch (the travel distance) and duration (the travel time), the waves near the property grow higher. The outer coast of the property is hit by an average of 4 to 7 storms a month during the winter, but almost none during the summer with the exception of occasional typhoons (Figure 2-8).

As a result of such activities, ROK's west coast becomes wave-erosion-dominated because of storms in winter and changes into tide-deposition-dominated in summer. The alternation of summer deposition and winter erosion are clearly evident in the open-coast tidal flats along the west coast of ROK. Among the components of the nominated property, it leaves a particularly

clear geological record in outer parts of the Gochang and Shinan Getbols, which are characterized by wave-dominated sand flats influenced by winter monsoon activities. This phenomenon is a critical feature affecting the redistribution and stable deposition of sediments onto the tidal flats in the property. The warm and humid temperate climate of the Korean Peninsula has resulted in sufficient chemical weathering and contributes significantly to the sedimentation that forms the tidal flats.

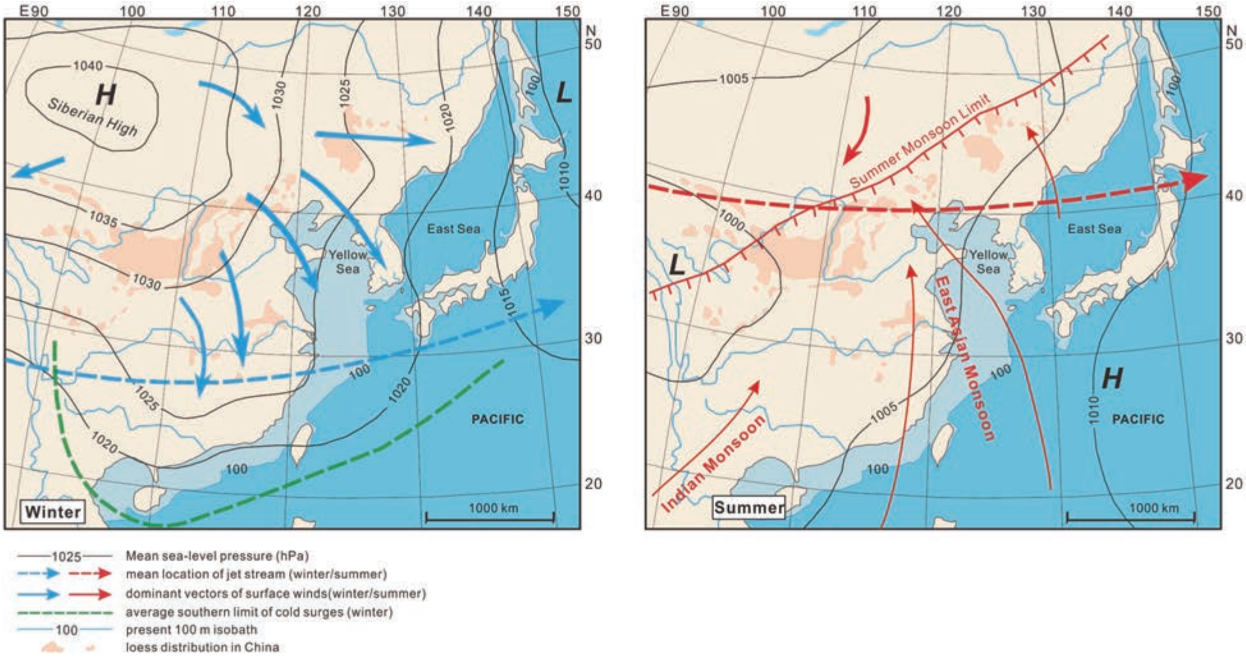


Figure 2-7. Seasonal changes in the wind system of the East Asian monsoon area (modified after Yi, 2011)

• Localized Heavy Rains and Typhoons during Summer

The annual average precipitation in ROK reaches about 1,300 ㎜. About 60% of the precipitation is concentrated between June and September with rains as heavy as over 400 ㎜ per day, often accompanying a typhoon. Such strong rainfall delivers large amounts of suspended sediment to the ROK's west coast. The Yellow Sea is one of the basins that contains the world's largest volumes of terrigenous sediments, due to its climate, large rivers nearby and the geological and the climatological characteristics of drainage basins.

Typhoons created in the southwest part of the Pacific Ocean bring heavy rains and strong winds as they visit the property several times a year in summer and early autumn (Figure 2-9). One or two typhoons in a decade can be strong enough to erode up to 10 to 30 ㎝ of the upper layer of the tidal flats. These typhoons erode and redistribute much of the surface sediments of tidal flat from the nominated property. The tidal-flat surface disturbed by human activities returns to its natural state within three months after a typhoon attack (Chun et al, 2004b). This plays a crucial role in maintaining the overall health of the sedimentary system and associated habitats.

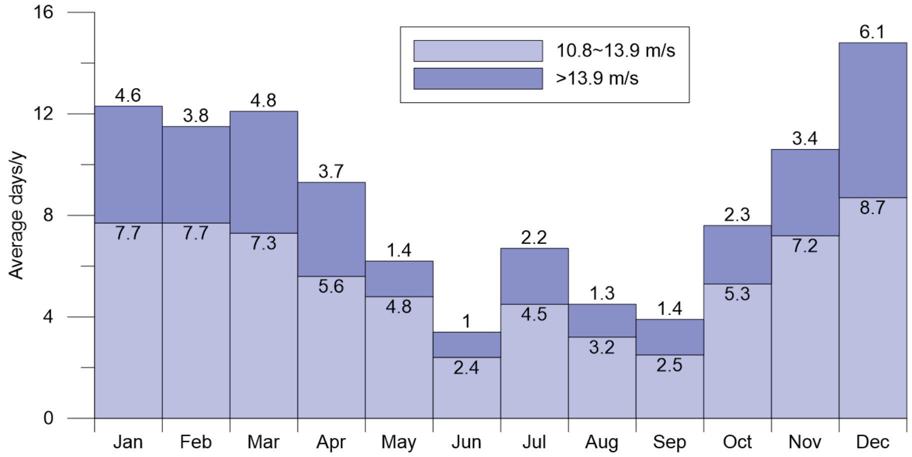


Figure 2-8. Annual distribution of the frequency and intensity of storm winds over the period 2007-2017

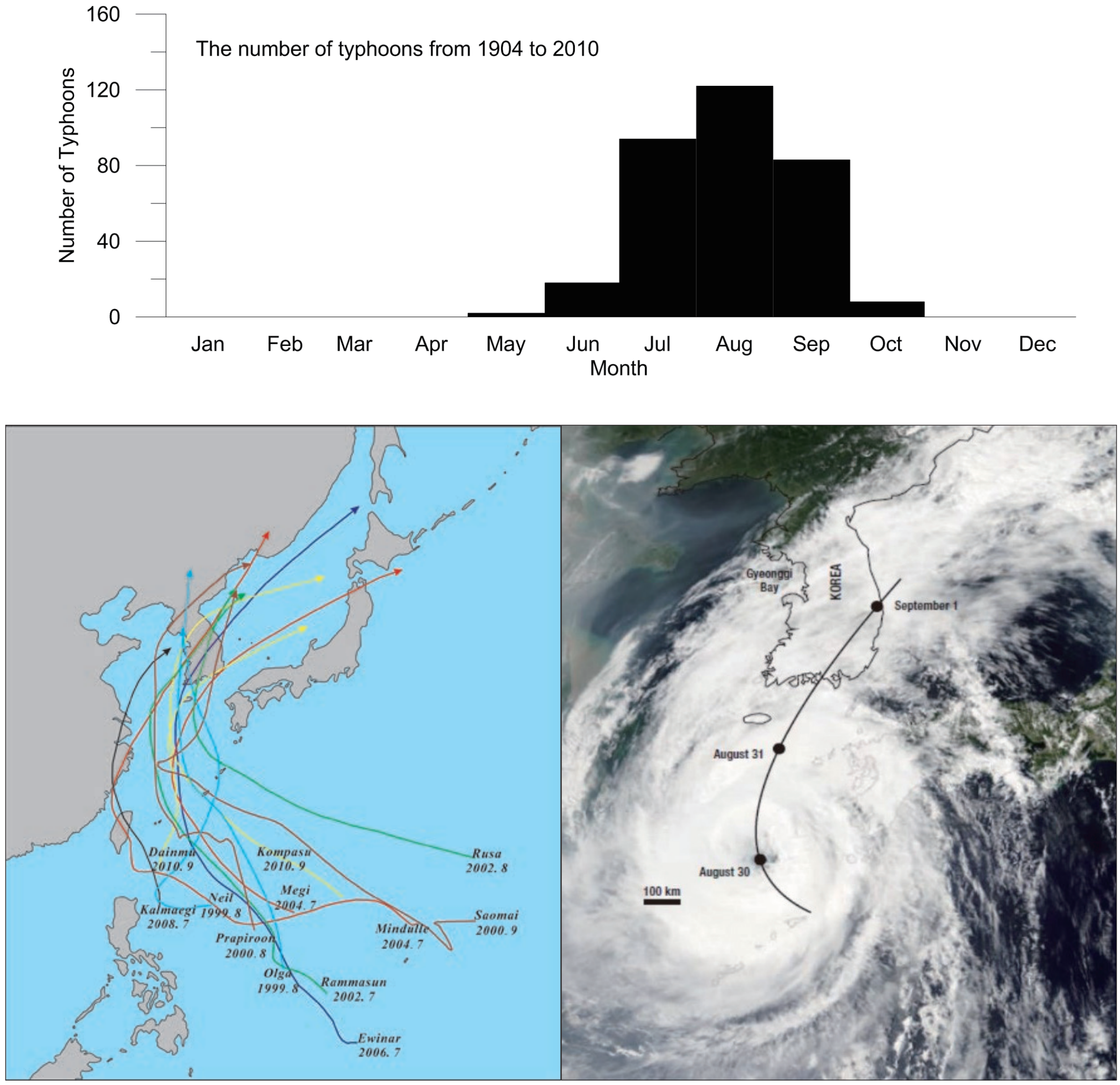


Figure 2-9. Frequency of typhoons that passed through the Yellow Sea from 1904 to 2010, the simplified pathways of typhoons since 2000 and an image of Typhoon Rusa (August 2002)

2.a.ii.4 Circulation of Sediments: supply and transport

• Supply of Terrigenous Sediments

Due to the high mountain ranges of the eastern Korean Peninsula, slopes to the east coast are narrow and steep, whereas those to the west coast toward the Yellow Sea are wide and gradual. Thus, the peninsula clearly shows an asymmetrical, high-east-low-west terrain. This is why most of the major rivers on the Korean Peninsula flow to the west into the Yellow Sea. Terrigenous sediments from the rivers, including Amnokgang (Yalu), Daedonggang, Hangang and Geumgang rivers (over 400 ㎞ long) as well as Yeongsangang River (150 ㎞ long) which are all major rivers flowing to the coasts of the Yellow Sea, are as bountiful as those found in other major rivers around the world. This is partly due to active chemical weathering under warm and humid temperate climate. This process produces large quantities of terrigenous sediments enriched in nutrients. With the aid of perennial rivers, the sediments are continuously transported to the sea. Geumgang and Yeongsangang rivers together, for instance, supply an average of 10 ㎦ of sediments per year to the coastal zone of the property.

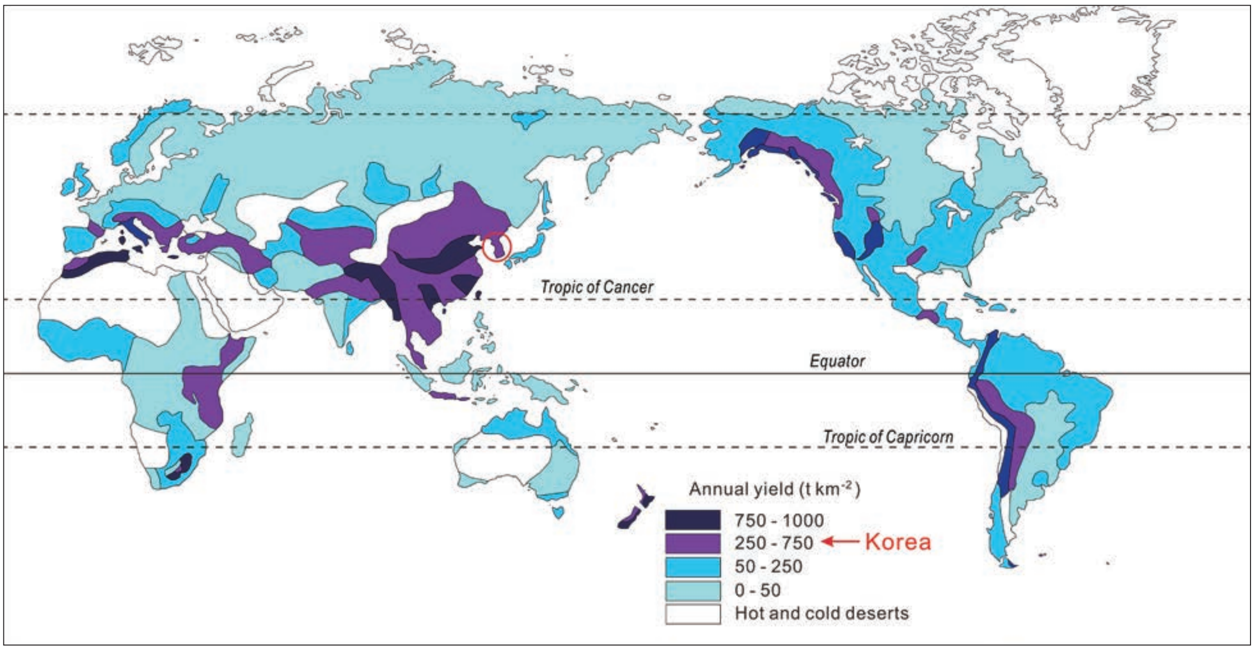


Figure 2-10. Map of the world indicating annual terrestrial sediment yields (after Smithson et al., 2002)

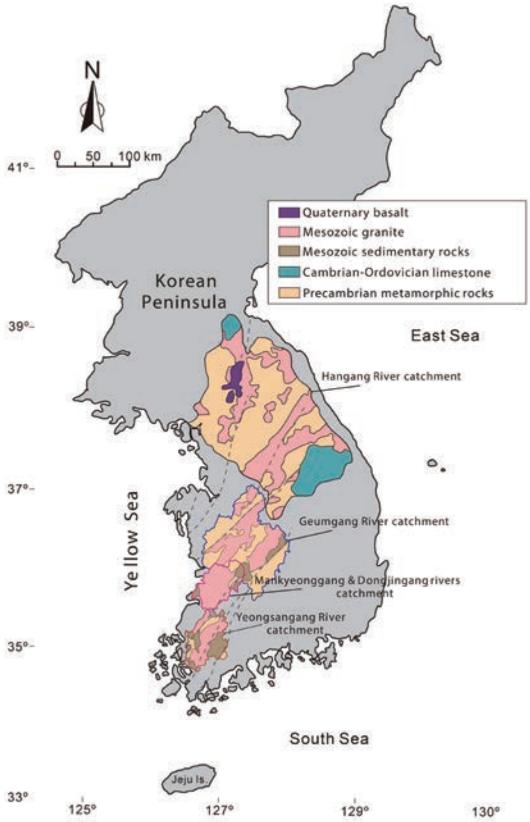
The coasts along the Yellow Sea are one of the areas that receive the largest volume of terrigenous sediments in the world. The western coasts, in particular, receive the largest volume of terrigenous sediments due to multiple environmental factors – geologic, geomorphologic and climatic conditions as well as the basin areas being drained. The supply of sediments to the western coasts outpaces the increasing rate of accommodation space induced by sea level rise. This explains why most of the tidal flats here are of the deltaic-estuarine type. The eastern coast of the Yellow Sea also sees a lot of terrigenous sediments flowing into the Yellow Sea. On the eastern coast, the sea level rise has created more space for the sediments to accumulate and the riverine sediments from the Korean Peninsula has filled that space continuously. Also, multiple factors including currents with macrotidal range, waves caused by the East Asian monsoon climate and the ocean currents that flow in the Yellow Sea all contribute to the repeated sedimentation, erosion and transportation, ultimately pushing the sediments towards the shore and thus forming the tidal flats of the nominated property.

• Transport of Sediments

When torrential rain falls in summer, sediments transported from Geumgang and Yeongsangang rivers (Figure 2-11) are temporarily stored near the coast in the front of estuaries. The fine-grained sediments lying on the upper part of tidal flat sediments are resuspended by strong waves in winter and are transported further to the southern coasts by the West Korea Coastal Current and redistributed onto the intertidal flats by tidal currents.

The resuspended fine-grained sediment passes through Seocheon Getbol near Geumgang River estuary and then onto Gochang Getbol until they arrive at Shinan Getbol by the seasonal coastal process. Some fine-grained suspended sediments make the trip to Boseong-Suncheon Getbol within Yeojaman Bay in the South Sea. Parts of the suspended sediment even voyage out to the open Yellow Sea, pushed along by the coastal current, to be deposited onto the Heuksan Mud Belt (HMB) (Figure 2-12). The HMB, on the inner continental shelf, serves as a reservoir of muds and doubles as a storage for the stable sedimentation of the property.

The volumes of suspended sediment reaching the south coasts are relatively small compared to the sediments accumulating in other parts of the property. However, they continue to move eastward carried by the Jeju Warm Current (JWC in Figure 2-5), one of branches of Kuroshio Current, and eventually settle onto the sea floor near coasts or inside Yeojaman Bay where wave energy is weak. Sediment that does not reach the bays of the southern coasts is deposited in the subtidal zone, accumulating as the Central South Sea Mud (CSSM). The suspended sediment that successfully moves from Geumgang River to the entrance of the Yeojaman Bay ends up by being deposited in Boseong-Suncheon Getbol, a part of the nominated property. Therefore, the property is characterized by a single sedimentary system from source (Geumgang River) to sink (Yeojaman Bay).



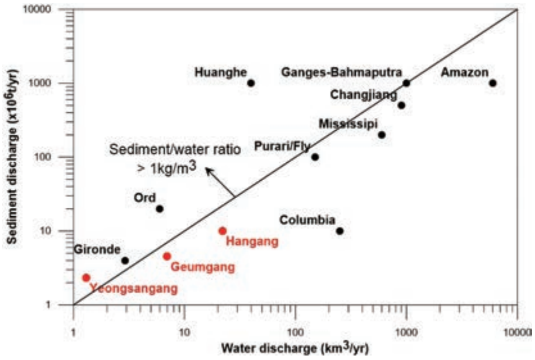


Figure 2-11. Bedrock geology in Hangang, Geumgang and Yeongsangan rivers catchment and their water and sediment discharges compared to other well-known rivers (modified after Smithson et al., 2002; Walling and Webb, 1983; Wright and Nittrouer, 1995; Chough et al., 2004)

• Dynamic Circulation System of Suspended Sediments

The characteristic features of the nominated property – numerous islands, complex coastlines, deep tidal channels and macrotidal range – help ensure the dynamic circulation of tidal currents. At the same time, waves, whose energy regime changes seasonally under the continental monsoon climate, and summer floods dynamically refresh the whole circulation of supply, reworking, transport and redistribution of suspended sediments. The tidal currents in the property change their speed and direction dramatically due to the geomorphological characteristics, resulting in complex inner tidal channels and various sedimentary sequences of tidal flats. In addition, the fast running currents in deep tidal channels between islands cause erosion or nondeposition at the channel base. Consequently, deep tidal channels are maintained even in the inner parts of the property despite slow sea level rise and the rapid sedimentation of mud flats around the island coasts. Tidal ebb currents rushing southward in the inner parts of the property even move suspended sediments far offshore, contributing to the formation of a sedimentary circulating system in the property as a whole and probably to a uniform redistribution of sediments.

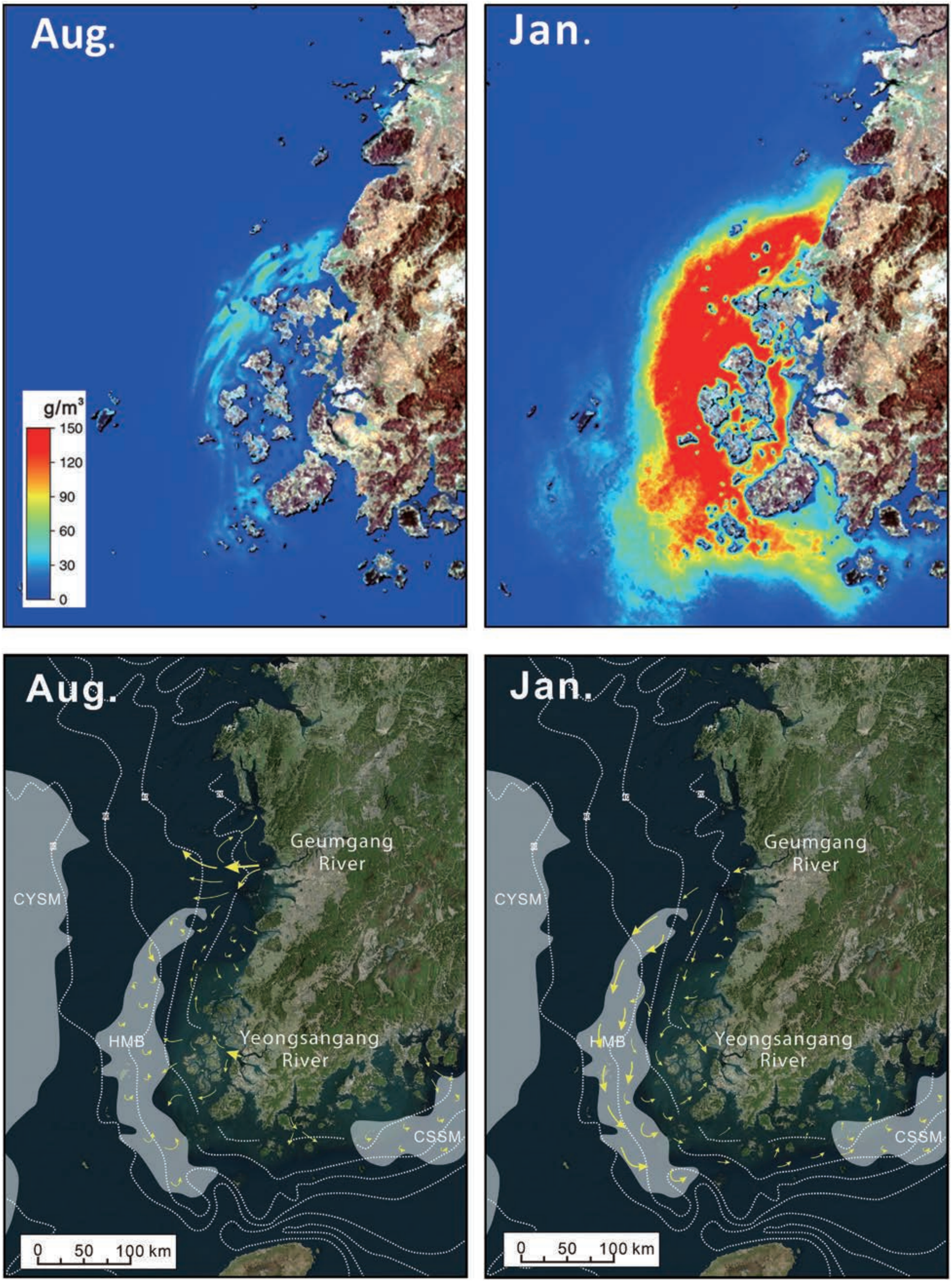


Figure 2-12. Satellite images of suspended sediment concentration and distribution and its transport pattern in the South and West Coasts of ROK (Chun, 2018). HMB, Heuksan Mud Belt; CYSM, Central Yellow Sea Mud; and CSSM, Central South Sea Mud

2.a.iii Geological and Geomorphological Features

2.a.iii.1 Geological Diversity and Seasonal Change

The nominated property is composed of numerous small-scale tidal flats in which the sedimentation in each tidal flat may differ according to the difference of the hydraulic energy that changes by season, complicated topography and the distance from sediment source. Each tidal flat is characterized by a different topography and distinctive physical features (sediment supply and interaction and reactivation between tides and waves). As a result, each tidal flat has evolved into a coastal environment that houses diverse habitats including mud flats, sand flats, mixed flats, gravel beaches, rocky substrates, tidal beaches, sand dunes, tidal channels and tidal gullies. The location of these tidal deposits also differs depending on the relative strength of the tidal current and wave, as well as the distribution and location of the islands. In the tide-dominated inner archipelagic area, thick mud flats and deep tidal channels have developed. But on the wave-dominated outer parts of the archipelago, sand flat, gravel beach, rocky substrate, tidal beach and sand dune have developed (Figure 2-13). Various transitional habitats are also formed due to the physical and/or seasonal changes especially in the northwestern and southwestern corners of some islands located in outer parts.

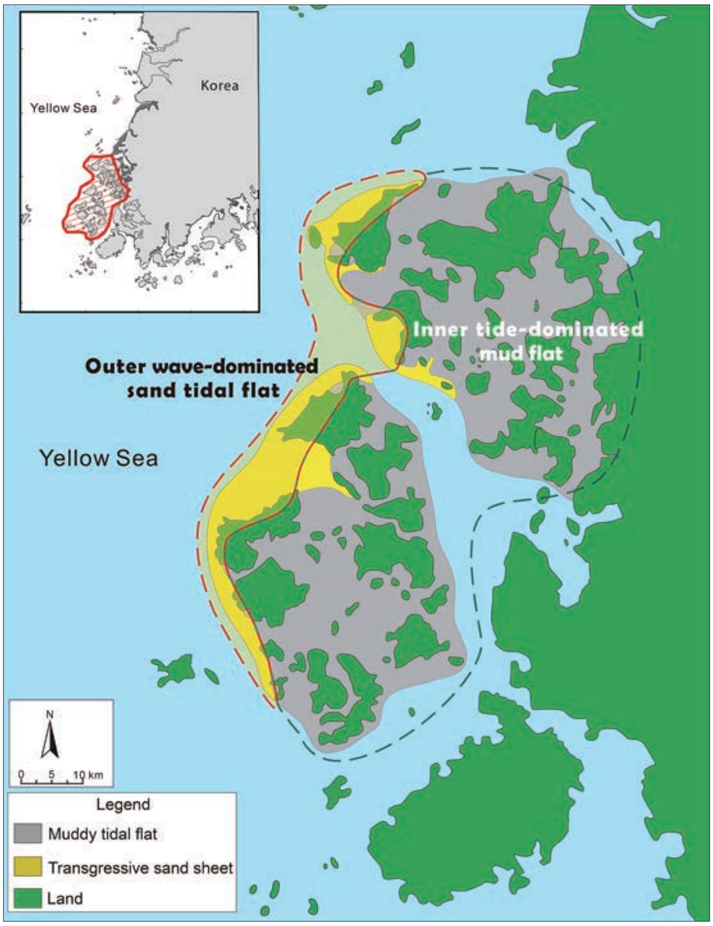


Figure 2-13. Surface sediment distribution in Shinan Getbol, displaying the typical sediment pattern of island type (archipelagic) tidal flats under East Asian monsoon climate system (Chun et al., 2015; Chun, 2018)

Seasonal movement of mixed-flat areas is seen on the coasts where waves compete with tides. The diverse physical features associated with the macrotidal range and many islands craft complex tidal creeks of various shapes on the mud flats. This physical diversity maximizes not only geodiversity but also biodiversity. Event processes such as typhoons in summer or formidable storms in winter produce the characteristic sedimentary bodies, which include typhoon deposits, storm deposits (tempestites), cheniers (elongate shelly ridges) and sand-gravel strings. These variable sedimentary bodies offer diverse habitats for the organisms.

Furthermore, some tidal flats in the outer parts of the property exhibit seasonal changes: some mud flats change into sand flats or mixed flats, governed by geomorphologic factors and monsoons. For instance, the mud layers made up of summer sediments on the outer parts of Gochang Getbol are eroded by 5 to 10 ㎝ in winter, which transform into sand flats. The outer parts of the property are also hit by powerful typhoons in summer and each invasion erodes the mud flat surface by 10 to 30 ㎝. This erosion is again rapidly compensated by a seasonal cycle of erosion and recovery. In contrast, the inner parts have no or very weak seasonal changes even by strong wind in winter time and typoon in summer, because they are protected by rocky islands. As a consequence, the outer or the western parts of numerous islands of the property show a wave-dominated coastal environment, whereas the inner parts develop wide, tide-dominated wide mud flats.

2.a.iii.2 Geomorphological Diversity and Types of Getbol

The archipelagic landforms refer to the areas where tectonic features and past climate change have resulted in erosional landforms with high peaks and low valleys, that eventually became submerged in the course of sea level rise. The nominated property has immensely diverse terrains. It has rocky shores which rise above and fall under the water continuously by tides, as its altitude is near the sea surface; it also has tall islands over 300 m in elevation. Thus, it furnishes a variety of habitats together provided by diverse landforms and various substrates. The habitat diversity is further reinforced by the compound effect of tidal currents and waves.

Especially, the area where many islands are distributed has a more complicated coastal environment, because of the geomorphology of the archipelagic features combined with significant tidal action. Because of the surrounding archipelagic geomorphology, tidal currents traveling through the islands in the inner parts flow rapidly along tidal channels. Here, fine-grained sediments cannot settle due to the speed of the tidal currents. Instead, those fine-grained sediments are transported toward the island shores where weaker currents enable deposition. Sediments either build mud flats here or are transported to the open sea in suspension. On the other hand, the outer side of the archipelagic tidal flats are exposed to waves and longshore currents that encourage formation of wave-dominated sand flats, tidal beaches, sand dunes and some rocky intertidal areas.

The nominated property can be categorized according to geological and geomorphological characteristics. The relationships between the island and adjacent mainland determine the different categories (Figure 2-14). All the Getbol types are in one way or another associated with islands. The first, 'estuarine type', experiences a depositional regime of suspended sediment around islands near river mouths. The second, 'open-embayed type', shows a deposition of suspended sediment around islands developed near and/or in embayments. The third is an 'archipelago type', in which numerous islands located close to mainland shore induce the deposition of suspended sediment between islands. The final type is a 'semi-enclosed type', in which island located within a bay trap sediments supplied from the land. The outer parts of the archipelago type have the features of the open-embayed type. Between islands, on the other hand, the mud flats show stable sedimentation. The two, therefore, can be distinguished. The open-embayed type may have similar shape and sedimentation process in the initial stage of development. According to these categorization, Seocheon Getbol represents the estuarine type, Gochang Getbol the open-embayed type, Shinan Getbol the archipelago type and Boseong-Suncheon the semi-enclosed type, together defining the serial sites of the nominated property.

a. Estuarine Type b. Open-embayed Type c. Archipelago Type d. Semi-enclosed Type

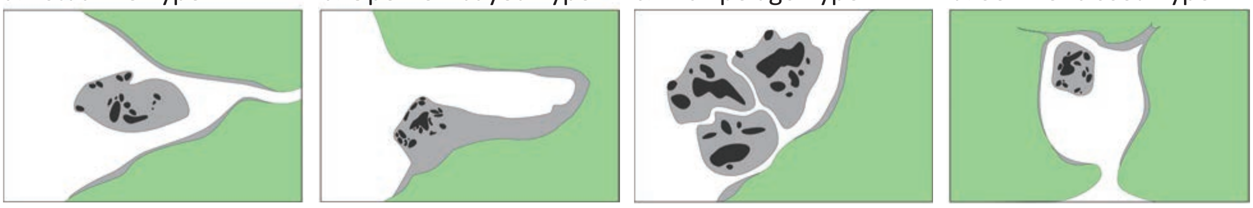


Figure 2-14. Various types of Getbol by geomorphological characteristics (Chun, 2018)

2.a.iii.3 Formation of Thick Mud-flats

• Formation of Inner-side Thick Mud-flats

Sea level rise since the Last Glacial Maximum enabled sea waters to invade coastal areas of the eastern valleys of the Yellow Sea. At the deep valleys, tidal channels started to form by macrotidal currents, rushing into and out of the valleys. The tidal channels were able to maintain their depth due to the erosion processes of rapid tidal currents despite the ample supply of mud sediments onto the inner side of area which consists of numerous islands. The suspended sediments introduced by tidal currents were deposited on both sides of the tidal channels during high tide, forming narrow mud flats. As sea level continued to rise, the width and depth of the mud flats increased. Nonetheless, the depth of tidal channels was maintained since the speed of the currents running through the channels accelerated at the same time. As a result, thick intertidal mud flats were formed by vertical aggradation on the flank of channels in the inner parts of the islands, except for the bottom of tidal channels.

Unlike the inner parts, the outer parts of the islands go through winter erosion and summer deposition because of the hydrodynamics in the eastern regions of the Yellow Sea.

Sea level rise and subsequent increased wave activity have produced a transgressive erosional surface on sand-flat layers, which have moved towards the land, repeating the process of erosion and deposition. The marine transgression continued to erode mud and mixed flats on the upper tidal-flat surfaces and its shoreline moved in an inland direction. The Holocene sedimentary deposits in the outer parts are mostly thin (0.5 to 5 m) and only parts of the preexisting mud flats remain due to the transgressive erosion. With the continuous rise in sea level, the property has witnessed a sustained formation of thin mud flats, laterally-migrating transgressive sand flats in the outer side and thick, vertically-aggraded mud flats inside.

The mud flats are found around the inner sides of the many islands. For about 8,500 years, Holocene mud sediments reaching more than 25 m thick have accumulated between the basement rock islands in a very stable and continuous manner in most places (Figure 2-15; Table 2-1). The surface of all mud flats in the inner side of the islands has kept up with the mean sea level rise. Their grain sizes and sedimentary structures of mud sediments are very similar to those of the upper intertidal mud flats and display a fining-upward, albeit weak sequential pattern. These sedimentary features are commonly observed when mud flats on the upper intertidal zones have formed following the sea level rise. It means that for 8,500 years, a sedimentary sequence of 25 m or more has been deposited on the upper intertidal mud flat. This is good evidence that the equilibrium between the sediment supply and the increasing rate of accommodation space induced by the sea level rise has been maintained for this long period. This stabilized and long-sustained intertidal mud accumulation on coastal zone is a critical, ongoing geological process and thick Holocene intertidal mudflat may be a unique characteristic of the property.

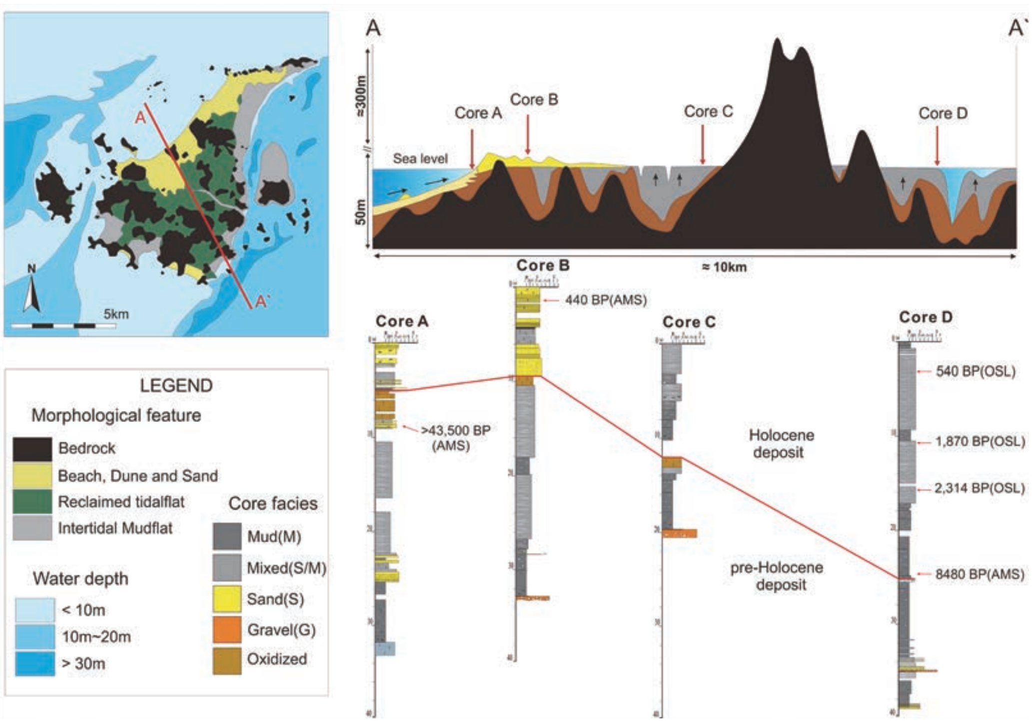


Figure 2-15. A representative cross section showing the Holocene and Pleistocene sequences in the Imjado Island of Shinan Getbol (Chun et al., 2015; Chun, 2018)

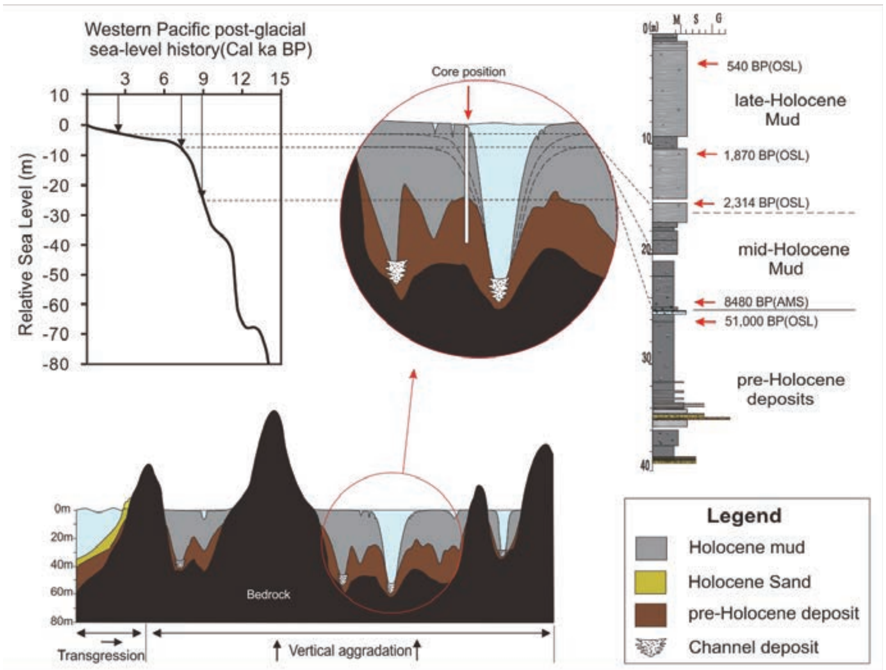


Figure 2-16. A schematic diagram of cross profile near Imjado Island showing the thickness of mud flats adjusted with sea level curve (Chun et al., 2015; Chun, 2018)

Table 2-1. Thickness of Holocene intertidal mud flat sequences (<9,000 yr BP) in the nominated property based on core data

Components	Tidal Flat		Holocene Sedimentary Sequences	
			Upper Sequence	Lower Sequence
Seocheon Getbol	Inner	Type	Mud Flats	Mud Flats
		Thickness	> 6 m	
	Outer	Type	Sand Flats	Mud Flats
		Thickness	~ 3 m	> 3 m
Gochang Getbol	Inner	Type	Mud Flats	Mud Flats
		Thickness	> 20 m	
	Outer	Type	Sand Flats	Mud Flats
		Thickness	~ 5 m	~ 3 m
Shinan Getbol	Inner	Type	Mud Flats	Mud Flats
		Thickness	> 25 m	
	Outer	Type	Sand Flats	Mud Flats
		Thickness	> 4 m	~ 6 m
Boseong-Suncheon Getbol	Inner	Type	Mud Flats	Mud Flats
		Thickness	> 4 m	
	Outer	Type	Mud Flats	Mud Flats
		Thickness	> 4 m	

About 8,500 years ago, the mean sea level was 10 to 15 m lower than the present. Most tidal flats around the world began to be formed at this time. Considering this sea level change, the thickness of the tidal deposits around the world should be approximately 15 m or thinner. Actual thickness of intertidal deposits is generally about 6-10 m across the world and that of mud layers on the upper intertidal deposits is even thinner.

Where there is a high supply of terrigenous sediment, deltaic-estuarine tidal flats tend to have very thick tidal sedimentary sequences including subtidal layers when the sea level rise and sediment supply are balanced. Despite this potential, most of the deltaic-estuarine tidal flats in the world usually do not contain sedimentary deposit over 10 m in thickness. It is because delta fronts cannot be free from the influence of sea level rise. Besides, deltaic sediments tend to prograde towards offshore instead of aggrading vertically. Therefore, tidal Holocene mud flats are not commonly thick. Exceptionally in Wadden Sea tidal flats which correspond to lagoonal setting protected by barrier islands, the thickness of the Holocene tidal-flat sequence including subtidal and channel deposits reaches up to 18 m .

Very thick intertidal mud sequences have formed in the middle-to-upper tidal flats, dominantly by tidal currents with large suspended loads. The Holocene intertidal sequences in the property started to deposit below 10 to 25 m in depth (Table 2-2). The intertidal mudflats thicker than 25 m have also formed in some places in the nominated property over the last 8,500 to 9,000 years BP, when sea level was roughly 15 to 20 m lower than the present. This fact may seem like a scientific contradiction. This is partly explained by the fact that the coasts of the nominated property have experienced higher tidal range than 4 m . However, the intertidal mud flats are developed at the middle-to-upper part of intertidal flat near and over mean sea level in the property area. Therefore, it is hard to fully explain the formation of the intertidal mud flats only with tidal difference, which are thicker than the height of sea level rise. The property is representative of macrotidal, archipelagic setting with deep tidal channels and sufficient supply of suspended sediments. About 8,500-9,000 years ago, macrotidal currents might have run through tidal channels situated 10 to 20 m lower than the sea surface (mean sea level) because of the macrotidal archipelagic characteristics. Tidal currents containing large amounts of suspended sediments contributed to forming the intertidal mud flats on the margin of deep tidal channels and on the flats between the tidal channels and rocky islands at high tide. As sea levels rose rapidly, the surface of the mud flats climbed rapidly as well, forming intertidal mud flats more than 25 m thick near the narrow margin of current tidal channels as of today (Figure 2-16). The property may be the thickest Holocene intertidal mud flats in the world ever known. It is also a unique tidal flat that has sustained the oldest and thickest and ongoing intertidal mud-flat formation that has occurred in the literatures.

Table 2-2. Comparison of the maximum thickness of inter-/sub-tidal mud flat deposits around the world

	Nominated Property	Open-coast tidal flat		Chenier plain tidal flat		Delta			Lagoon	
		King Sound, NW Australia	Chinese Coast, China	Gulf of carpentaria, Australia	Firth of Thames, New Zealand	Colorado River delta, U.S.A.	Mekong Delta, Vietnam	Yangtze River Delta, China	Georgia U.S.A.	Wadden Sea, Denmark, Germany, Netherlands
Thickness of mudflat sequences	> 25 m	< 6 m	< 10 m	< 6 m	< 6 m	< 1 m	< 10 m	< 10 m	-	< 18 m
	intertidal flat	intertidal flat	intertidal + subtidal flats	intertidal + subtidal flats	intertidal + subtidal flats	intertidal flat	intertidal + subtidal flats	intertidal + subtidal flats	marsh	intertidal flat

• Types of the Thick Mud-flat Sequences

Mud-flat sequences in the nominated property shows different characteristics and sequencial types according to geomorphological features, the location and altitude of the islands, the sediment supply and the pattern of tidal currents (Figure 2-17).

Type A is a sequencial type showing thick mud flats and very steep/deep tidal channels with islands that have high altitudes. Shinan Getbol is a Type A tidal flat, with its 25 m deep mud sediments in the intertidal area. The Optically Stimulated Luminescence (OSL) time stamp at the border lines of the layers is prior to the Holocene. The 25 m thick Holocene mud-flat sediments commence around 8,500 years ago, indicating that the mud sedimentation began to form on the intertidal area between channels and rocky coasts mainly due to vertical aggradation. Shinan Getbol, even with the sea level rise, has a sedimentation environment where the current tidal sedimentation via vertical aggradation is maintained in a stable manner.

Type B is representative of a type having low sedimentation rate with thin tidal-flat sequences in the inner sides of the islands. The islands still keep the initial shape of archipelagic islands with high relief. Boseong-Suncheon Getbol is a Type B tidal flat. It also seems to be deficient in supply of suspended sediments or is far away from the source. Boseong-Suncheon Getbol are less than 6 m of thickness of its mud-flat sequences in intertidal area.

Type C has only a few islands remaining and is mostly covered by mud flats. Partially, the wave-dominated and transgressed sand flats have begun covering up the mud flats from the outer sides. Seocheon Getbol is a Type C tidal flat with most of its tidal channels in between the islands covered with mud and has a more than 6 m thick intertidal zone mud sediments. If sea level rises continuously, the Seocheon Getbol has a high probability of its entire mud flats being covered up by sand flats.

In Type D, most of the rocky islands are covered by sediment. The upper layers of the inner side mud flats have turned into wave-dominated sand flats. Gochang Getbol is a Type D in which most of the archipelagic islands and tidal channels are covered with sand flats that transgressed due to sea-level rise. At the depth of 20 m, the boundary between pre-Holocene layers and Holocene sediments is observed, which can be dated at 8,300 years BP by the OSL method.

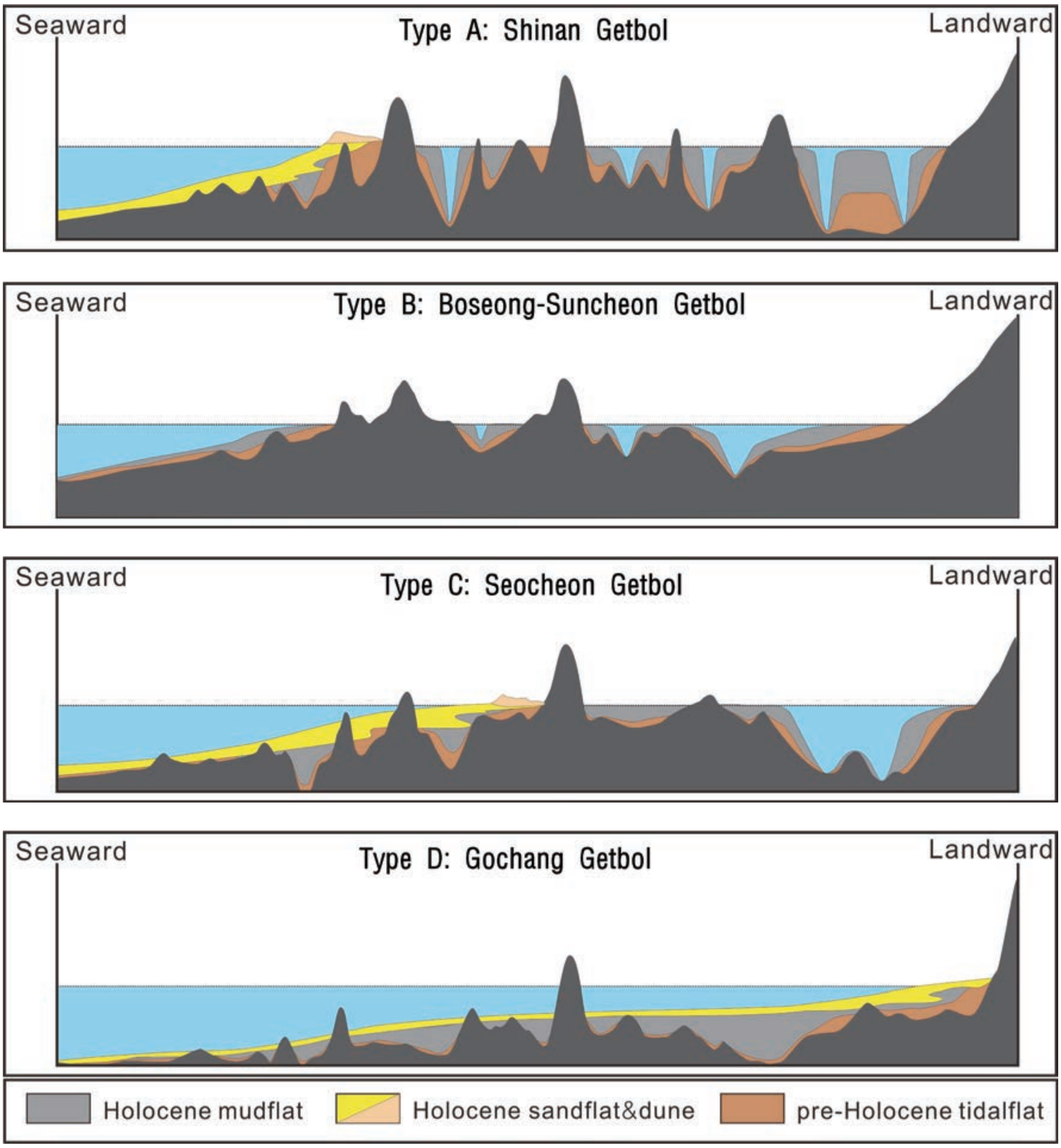


Figure 2-17. Schematic diagrams of cross profiles showing formation of Getbol sequences (Chun, 2018)

2.a.iv Habitats and Ecological Features

2.a.iv.1 Evolution of Communities in the Ecosystem by Getbol Formation

The formation of the nominated property began about 8,500 years ago, giving birth to the first mud flat in the property. The inundation by Holocene sea-level rise gradually spread northward, reaching the nominated property area to form mud flats which started to change into sand-dominated flats 3,000 years ago on its outside, lasting to the present day.

When a habitat is formed on tidal flats, the primary producers are the first to nestle in and develop a community. Benthic invertebrates with a pelagic larval stage are then recruited, evolving into a stable community together with numerous polychaetes, clams and small crustaceans. With macrobenthos joining the community, the evolution of the community is greatly stimulated, allowing for higher biodiversity. Finally, the community enters a stable stage when carnivores such as waterbirds and mud octopuses (*Octopus minor*) start to appear and make the community structure more complex and stable.

For the mud flats in the property, the initial terrestrial rocky ecosystem is replaced with a community of primary producers as mud continues to be deposited. Afterwards, those that feed on organic matter in sediments, such as polychaetes, small gastropods, clams, and Japanese mud crabs (*Macrophthalmus japonica*) emerge as the dominant species with a large biomass. Their predators, mud octopuses and waterbirds, join the habitat and settle as a keystone species, completing the transition of the community into a stable condition.

Mud octopuses are carnivorous predators that have a preference for Japanese mud crabs. It is a keystone species that controls the entire community. Mud octopuses live in U-shaped burrows that reach 1 m deep into the mud, and play an important role as ecosystem engineers that influence the habitat environment of other living organisms in the tidal flats, because its burrowing activities oxygenate the muds (Figure 2-18).

Mud octopus is also an important fishery resource that sustains the lives of the local fishermen (Figure 2-19), the annual catch of mud octopuses in Shinan Getbol being about 600 tons. To catch them the fishermen utilize an ‘octopus long line’ that use Japanese mud crabs as bait. Some fishermen will also rummage in the muds to find the burrows and plow the mud octopuses up by hand or use a small shovel to find them. These traditional fishing activities are based on the indigenous knowledge of local residents and take place within ecologically sustainable bounds. Locals eat the octopus raw, chopped up, grilled, or boiled, enriching the diversity of local cuisines. Mud octopus is considered a symbolic species that is closely interrelated not only to the ecosystem but also to the economic, social, and cultural lives of the local residents.

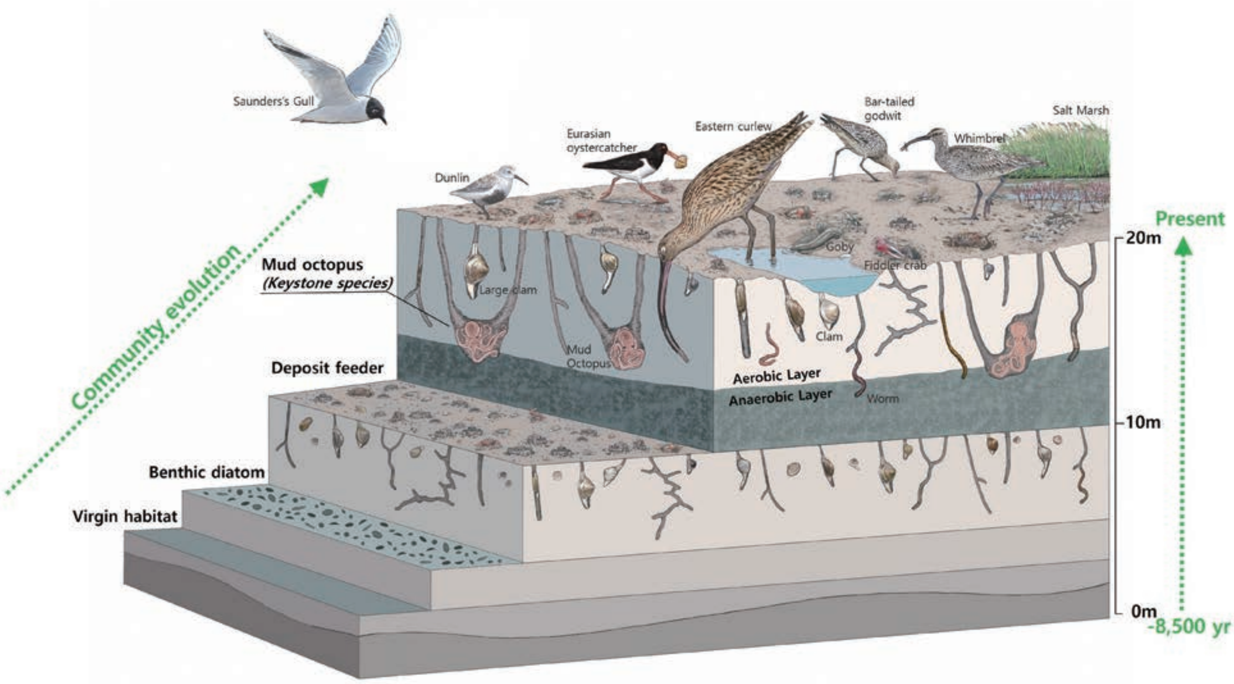


Figure 2-18. Schematic diagram of the community evolution on mud flat habitat

Figure 2-19. Mud octopus, a keystone species in muddy habitat

Sand flats are formed when sands supplied by rivers and eroding cliffs are transported to shorelines. Eventually a community dominated by clams, filter feeders that live on organic matter in the water, evolved here. Such a community also accommodates amphipods and polychaetes, which feed on organic matter in the sand. In particular, hard clams (*Meretrix lusoria*) joined and completed a stable community structure. Their density may be low but their biomass per individual is high. Eventually, waterbirds became top predators and functioned as a keystone species in this community (Figure 2-20). This is why the property offers an indispensable stopover site for migratory birds including some endangered species.

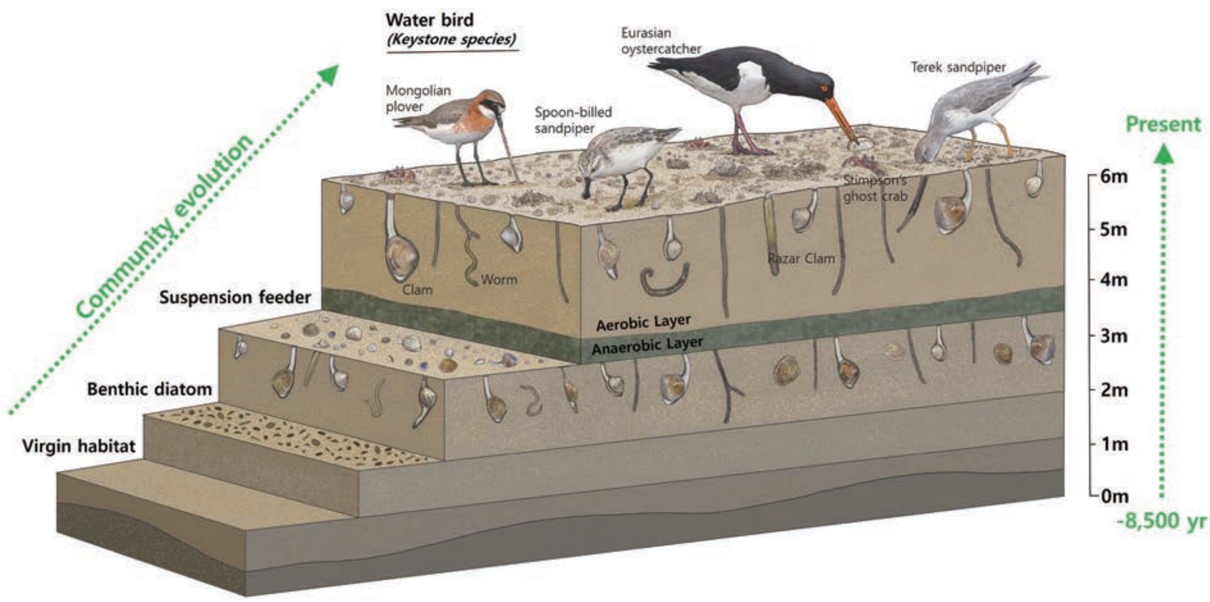


Figure 2-20. Schematic diagram of community evolution on sand flat habitat

2.a.iv.2 Food Chain and Energy Flow

A well-established food chain and an effective energy flow are prerequisites to maintaining active ecosystems within the property. An active energy transfer from primary producers to last consumers and the decomposition of organic matter by aerobic bacteria are essential for proper energy flow (Figure 2-21). This energy flow allows a variety of species to survive in the tidal flats and to maintain high biodiversity.

The food chain in mud flats of the property is initiated from benthic diatoms (Figure 2-22), whereas in rocky habitats benthic diatoms and marine algae are the primary producers of the food chain. The primary producers here are directly consumed by deposit feeders such as Japanese mud crabs, fiddler crabs, polychaetes, clams, and gastropods. These benthic organisms are again fed upon by top predators, including mud octopuses, waterbirds, and starfish. This prey-predator relationship maintains equilibrium in the dynamic ecosystem. Continuous visits of migratory birds and the high proportion of internationally endangered species are further strong evidence for active ecosystem processes and the stabilized evolution of communities.

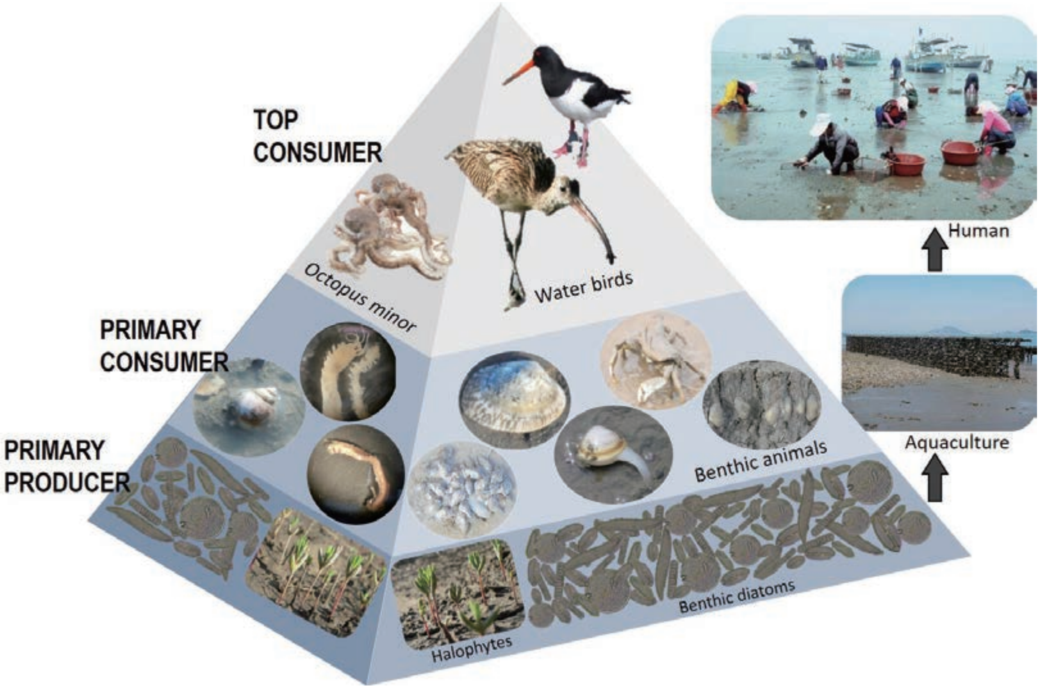


Figure 2-21. Food pyramid in the tidal flat ecosystem

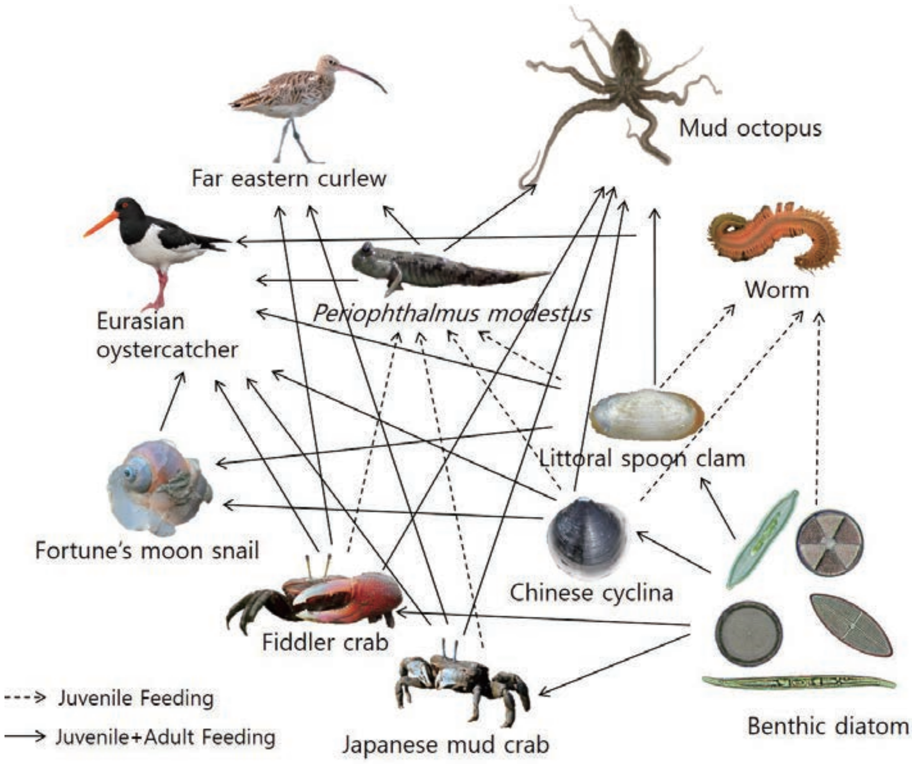


Figure 2-22. Food web in the tidal flat ecosystem

Plovers feeding on tidal flats almost double their weight on average to prepare themselves for a long journey. They need to uptake sufficient protein and fat at their stopover sites to continue their migration. The large population of plovers visiting the property proves that there is enough energy supply.

Figure 2-23. Dunlin (*Calidris alpina*) running with just-caught polychaete worm

The property has four distinct seasons. Marine organisms breed in spring, and grow to the fullest extent in summer and fall enjoying abundant food. Despite its location at a relatively high latitude in the temperate zone, the property maintains stable ecosystem because it rarely freezes in winter and macrobenthos in tidal flats tend to burrow deeper to avoid cold weather.

High primary production and an efficient energy flow in tidal flats are evidenced by: (1) frequent visits of numerous waterbirds, (2) high biomass of benthic invertebrates as their prey and (3) large amounts of coastal fishery products for humans that live on the energy produced here.

It should be noted how long-lasting sustainable fishery activities by the locals in the property actually attest to a perfect balance among the different tidal flat organisms. Even with continued human activity, the richness of the ecosystem has rarely been affected. It is because local residents have been wise enough not to overfish using only their indigenous knowledge and methods handed down for generations (Figure 2-24). An example of the most simple energy flow from primary production to humans is laver (*Porphyra* spp.). Also, Manila clams and cockles are

important intermediators as they indirectly convey the energy of primary producers to humans. At both juvenile and adult stages they are consumed by others and thus play an essential role in completing an energy flow and a community evolution process in the nominated property. Thus, the property has enough area to maintain these two distinct community evolution patterns.

Figure 2-24. Cockle (*Tegillarca granosa*) harvest in Boseong-Suncheon Getbol

2.a.iv.3 Biotic Communities by Habitats

Depending on the type of substrates and their surrounding environmental conditions, mud flats, sand flats, and rocky substrates in the nominated property include their own unique biotic community. The seasonal differences produced by the East Asian monsoon climate and by rapid tidal currents running between numerous islands have generated a variety of complex habitats across the wide region.

The property, including numerous uninhabited islands and their surrounding mud flats, represents a unique, well conserved and interconnected terrestrial-coastal-marine ecosystem. Because each rocky-muddy, rocky-sandy and sandy-muddy substrate pairs forms individual sub-ecosystem of great complexity in this broad region, they are represented by very complicated smaller interconnected ecosystems. The types of ecosystem are as follows:

• Muddy Habitats

Mud flats in the property have been developed in areas where the influence of waves and tidal currents are not significant. These areas have narrow salt marshes. Flowing sediments along complex tidal channels actively bring and distribute mud and nutrients. Some mud flats are 90% made up of muds. But there are also mixed flats consisting of both muds and sands. Japanese mud crabs, which are deposit feeders, are commonly found in mud flats. Their carnivorous predators like mud octopuses and waterbirds join the communities as a keystone species.

Sufficient supply of organic matter is absolutely necessary to grow a stable community in muddy habitats and to maintain high biodiversity. Most of the organic matter is produced by primary production by benthic diatoms with the rest coming from salt marshes. As a variety of organisms with different feeding structures dwell in muddy habitats, high biodiversity is achieved and the community evolution processes become more complete. Even though planktonic jellyfish mainly swim and dwell in neritic or pelagic realms, sometimes they are left on mud flats during low tides. Fortunate nassa mud snails feed on them, thus making the energy transfer between the pelagic and the benthic ecosystem possible (Figure 2-25).

Figure 2-25. Fortunate scavenging mud snails (*Reticunassa festiva*) feed on full moon jelly fish (*Aurelia aurita*) during low tide

Densely populated deposit feeders like Japanese mud crabs, capitellid polychaetes, or fiddler crabs gain energy by eating mud containing organic matter and then are eaten by their predators. In addition, they burrow and thereby supply oxygen-rich sea waters into anaerobic layers that have insufficient dissolved oxygen in interstitial water (Figure 2-26). Their burrowing at the same time carries sediments upwards and enables decomposition of organic matter by aerobic bacteria, thus circulating nutrients. The habitats on the tidal flats in the property have brown aerobic layers of about 10 ㎝ in depth, the theoretical depth of the organism dwelling zone.

Spats of clams, polychaetes and brachyuran juveniles burrow down deeper as they grow. When fully grown, each species dwells beneath the floor at different depths, a phenomenon called an interspecific vertical distribution pattern. Even in the same aerobic layers, smaller ones prefer to live near the surface layer, whereas larger or those with remarkable burrowing skill tend to dwell in deeper layers, exhibiting clear intraspecific vertical distribution.

This is the result of adaptation for thousands of years, by managing to use deeper sediments vertically to avoid inter- or intra-species competition for space and to share the habitat resources more efficiently.

Figure 2-26. Polychaete worms dwelling in aerobic and anaerobic layers of the sediment

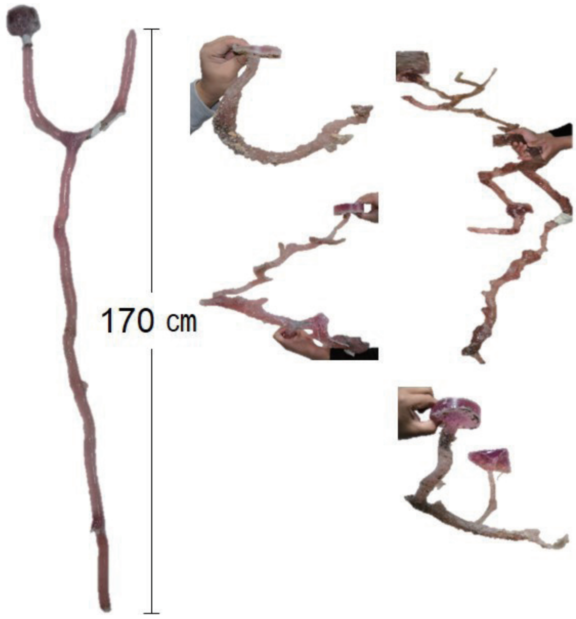


Figure 2-27. Burrows made by Japanese mud shrimp and crabs in the tidal flat

Those who live in anaerobic zones, below aerobic zones, have to find a way to survive such harsh condition or must shield themselves from the anaerobic environment by pasting mucus onto the inner surface of their burrows to create comfortable living conditions while bringing water down into their homes. Each macrobenthos has different level of burrowing capability depending on its body size. Clams with a long siphon – razor clams, soft clams and angel's wings (*Barnea davidi*) - live 20 ㎝ beneath the surface, while Japanese mud shrimps (*Upogebia major*) can build their burrows 170 ㎝ or more in depth (Figure 2-27).

Depending on the living depths of habitats, different sizes and types of organisms are eaten by different predators at different timings and depths (Figure 2-28). This enables a very efficient distribution of the food resources in the ecosystem. Small-sized amphipods, living on the surface of substrates, are eaten by waterbirds with short beaks. Larger organisms living further below are fed by waterbirds with longer beaks. As a result, bioturbation-induced ecosystem processes take place very actively in the nominated property and characteristic patterns of the vertical distribution can be established.

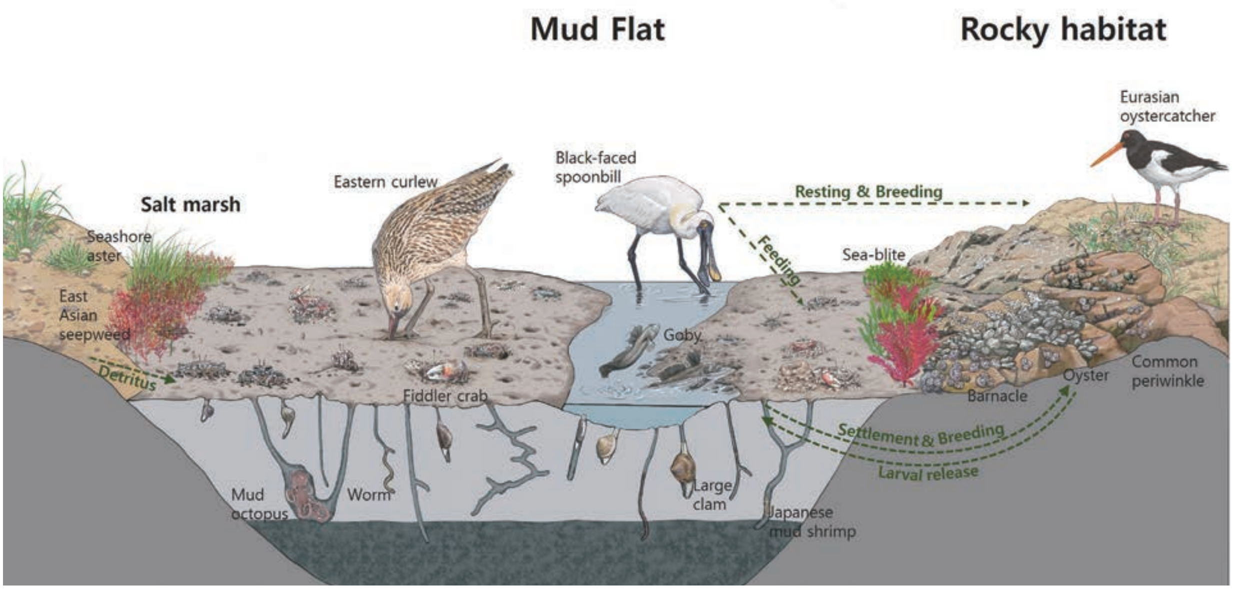


Figure 2-28. A schematic diagram showing the interconnected ecosystem in mud flats

• Sandy Habitats

Within the property, areas that face directly the open sea (the outer part of archipelago and open-coast tidal flat) are wave-dominated regions. In these tidal flat settings, distinctive ecosystems have developed on the gentle/wide sand flats and steep/narrow tidal beaches. Toward the land sand dunes are developed where dune plants grow. Compared to mud flats or rocky substrates, the habitat is simpler in these wave-dominated environments. The most common dwellers here are suspension feeders, clams, and detritus-feeding polychaetes and small-sized crustaceans. In this community, the keystone species are waterbirds who feed on the suspension and detritus feeders. The waterbirds regulate the density of certain species they prey on, enhancing the biodiversity in the region they belong to.

On the sand flats, suspension feeders such as surf clams (*Mactra veneriformis*) and hard clams (*Meretrix lusoria*) and deposit feeders including Yellow Sea sand snails (*Umbonium thomasi*) and milky fiddler crab (*Uca lactea*) are commonly found. The upper zone of sand flats that are closer to land is a favored site for mud pea crabs and Stimpson's ghost crabs, which live in burrows and produce sand granules through their feeding activities.

Primary producers such as benthic diatoms and phytoplankton in the water column build the base of the trophic level in sand flats. Their consumers are macrobenthos, mainly polychaetes and clams. Highly abundant polychaetes and clams in turn, are consumed by waterbirds (Figure 2-29). This process bridges the food chain starting from the primary producers and ending with the top predators.

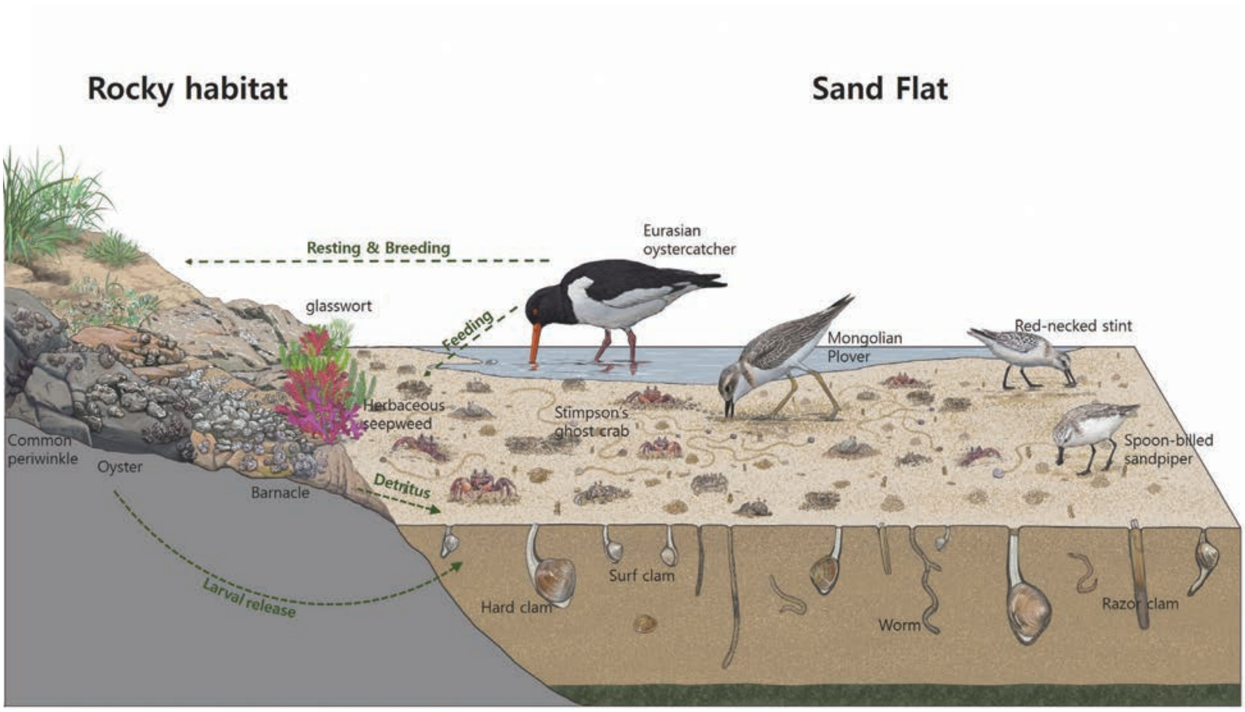


Figure 2-29. A schematic diagram showing the interconnected intertidal ecosystem in sand flats

• Rocky Habitats

The major supplier of organic matter on rocky habitats are benthic diatoms and marine macroalgae, the primary producers prospering on the surface of rocks. Herbivores who feed on them and the top predators who prey on these herbivores lead to even more vibrant ecosystem in rocky habitats.

Rocky ecosystems near mud or sand flats in intertidal zone are usually not developed as offshore rocky ecosystem. However, rocky habitats in the property offer variable physical possibilities and challenges to living creatures, depending on the bedrock's inclination and curvature, the amount of surface area facing the sea, and the duration and direction of exposure to air. Different physical conditions result in the formation of a variety of microhabitats in each of the rocky habitats thereby enhancing biodiversity in general and resulting in a vertical ecological zonation. For example, the exposure duration to air makes a difference on rocky habitats. In the upper layers, granulated periwinkle (*Nodilittorina radiata*) and the Korean common periwinkle (*Littorina brevicula*) are dominant. The middle layers are mostly inhabited by common sessile barnacles and Pacific oysters. The leaders of the lower layers are mussels or marine macroalgae. Common sessile barnacles and Pacific oysters are eaten by the Korean common dog whelks. The carnivores weak to air exposure, such as starfishes and gastropods, tend to dwell in the lower layers. Starfishes in particular serve as a keystone species that prevent any one organism type from dominating the entire rocky habitat and contribute to stabilizing the community with a high biodiversity.

Macrobenthos living on rocky habitats release planktonic larvae into the water column during their breeding season. Drifting larvae grow by consuming on phytoplankton (primary producers) but they are also eaten by other tidal organisms. The larvae soon finish drifting and settle onto a rock completing their life cycle and stabilizing the community.

Marine algae including seaweeds (*Sargassum thunbergii*), green laver (*Enteromorpha* sp.), seaweed fusiformes (*Hizikia fusiforme*), and sargassums (*Sargassum fulvellum*) serve as a habitat for herbivores, a nursery ground for juveniles, and a food source for humans. They also produce particulate organic matter by absorbing nutrients. Tide pools construct their own proprietary ecosystem where endemic species like gobies live. These tide pools are another important element of biodiversity in the nominated property with numerous rocky islands.

The rocky habitats also serve as resting areas for Eurasian oystercatchers after feeding themselves on mud or sand flats and flying off to nearby land for breeding. It is a representative example of the connected ecosystem where the linkage between tidal flats and land is evident.

2.a.v Biodiversity and Endangered Species

1,610 species of flora and fauna have been reported in the nominated property. In the neighboring land ecosystem 540 species of flora and fauna have been reported. Together it has been confirmed that over 2,150 species of flora and fauna are living in the nominated property (Table 2-3). In particular, 22 of the endangered species recognized by IUCN, including the spoon-billed sandpipers, are reported along with 47 species of endemic marine organisms that are found only in the property.

Table 2-3. Number of species reported in the marine and terrestrial ecosystems in the nominated property

Fauna / Flora	Number of Species
Benthic diatoms	375 (215.7 ㎎/㎡)
Marine algae	152
Halophytes	54
Macrobenthos	857
Waterbirds	118
Fishes	54
Vegetation	406
Insects	114
Birds	20
Total	2,150

2.a.v.1 Taxonomic Biodiversity

• Benthic Diatoms

As many as 375 benthic diatom species are found in the nominated property. Major dominant species among benthic diatoms include temporary-pelagic benthic diatom (tychopelagic plankton) and they frequently appear in every component site. In addition, coscinodiscus species, *Thalassiosira eccentrica* and *Amphora holsatica*, also boost the primary production as major dominant species.

Primary production (Chlorophyll-*a*) reaches up to 74.7-215.7 ㎎/㎡ providing a sufficient foundation for a healthy tidal ecosystem. As a primary producer, benthic diatoms are the foundation of the energy flow. They produce organic matter which accounts for 50 to 80% of the total primary production in tidal flats or in coastal waters, providing a basis for survival of numerous organisms. Benthic diatoms' primary production has strengthened the biodiversity and their high abundance has enabled the property to be a major stopover site on the East Asian-Australasian Flyway.

• Halophytes

The property is inhabited by 54 species of halophytes. Shinan Getbol has the majority of 42 species and Seocheon, Gochang, and Boseong-Suncheon Getbol contain 27, 25, and 24 species, respectively. Most of the representative halophytes around the world can be found in the property, and its coastal vegetation belongs to one of the nine major global vegetation groups called the Sino-Japanese Group (Table 2-4).

Halophytes build a new habitat in the upper intertidal to supratidal flats and they generally tend to spread rapidly when the salt level of soil is over 0.5%. They also enhance sedimentation and reduce erosion at the same time. As a result, they contribute to maintaining the habitats. From time to time, living halophytes are fed upon by animals on salt marshes, but in most cases, they are consumed by other organisms as a detritus in the process of being decomposed after death.

Organic matter generated by halophytes is quantitatively less abundant than that generated by benthic diatoms, and its quality is also inferior. Yet their detritus contributes to accomplishing the complete detrital food chain in the tidal flats. Taking up nitrates and phosphates, they prevent red tides in the coastal areas of the property and complete the energy flow of the ecosystem (Figure 2-30). The salt marsh vegetation is indispensable for the integrity of the ecosystem, as it forms quintessential ecotone for terrestrial, tidal, and marine ecosystem.

Table 2-4. Main groups of halophytes around the world

Group	Genus
1. Arctic group	*Puccinellia, Carex*
2. Northern European group	*Puccinellia, Juncus, Salicornia, Aster, Limonium, Triglochin*
3. Mediterranean group	*Arthrocnemum, Limonium, Juncus, Salicornia, Salsola, Suaeda*
4. Western Atlantic group	*Puccinellia, Juncus*
5. Pacific American group	*Spartina*
6. Sino-Japanese group	*Triglochin, Salicornia, Limonium, Suaeda, Atriplex*
7. Australasian group	*Salicornia, Suaeda, Triglochin*
8. South American group	*Spartina*
9. Tropical group	mangrove

* Underlined species are the genera present in the nominated property.

Figure 2-30. Common reed and *Suaeda japonica* community in Boseong-Suncheon Getbol

Figure 2-31. *Enteromorpha* growing abundantly on a rocky habitat in Gochang Getbol

• Marine Macroalgae

The property provides a suitable environment for a total of 152 marine macroalgae species. Marine macroalgae are vital primary producers for rocky habitats. Their diversity and biomass influences the transfer process of nutrients in rocky substrates and underpins the ecosystem's biodiversity (Figure 2-31). Moreover, they provide numerous microhabitats for rocky-habitat organisms quite different from those in the muddy or sandy substrates.

Interestingly, a variety of marine algae living on or being cultured in tidal flats or rocky substrates in the property are widely used as a food product for humans. Over 90% of edible marine algae produced here are laver. Others include sea strings, kelps, sargassums, sea staghorns, seaweed fusiformes, green laver, seaweed fulvescens and agars (*Gelidium amansii*).

Laver has been cultivated in large areas of lower intertidal and subtidal areas of the property. Laver grown from fall to winter in these tidal zones has been an important source of income for locals over 400 years. The laver production does not have an impact on the natural environment, so that laver production and harvest is sustainable. Seaweed fulvescens growing on the surface of tidal flats during the winter season is also consumed by humans.

Organic matter from these marine algae is an important food source for most of the marine organisms and humans around the coast of the property. They take up nutrients from the surrounding marine environment and this process contributes to the circulation of elements in the tidal flats. As a result, the biodiversity is increased and the community structures and functions are maintained in a stable manner.

• Macrobenthos

In the property, 857 macrobenthic species have been found. Among them, 649 are soft and 307 are hard substrate dwelling types. This accounts for 86% of the whole macrobenthic species diversity in Korean tidal flats with a total of 1,004 species (817 soft and 307 hard substrate dwelling types). Soft and hard substrates have different compositions of organisms, but organic interaction between substrates during their life cycle leads to enhanced biodiversity.

Among the 649 species of macrobenthos observed in the soft substrate, over 62% are annelids and molluscs which form a dense population on mud and sand flats. They deliver life energy to the entire ecosystem through vigorous feeding activities. Salt marsh also serves as an important habitat for the endangered benthic fauna.

A total of 307 species of macrobenthos can be observed on hard substrates (Table 2-5). Molluscs that attach to or crawl on rock surfaces comprise 45%. Arthropods that hide between or beneath rocks or attach to rock surfaces account for 34%. Literally, the rocky habitats in the property are paradise for these two types of macrobenthos.

Macrobenthos refers to organisms with a body size of over 1 ㎜. They can be commonly seen in tidal flats with the naked eyes. They provide waterbirds and humans with good sources of protein and bridge the energy flow of the marine ecosystem. Salt marshes, mud flats, sand flats and rocky habitats take in different kinds of macrobenthos, and the entire biodiversity grows accordingly. Macrobenthos with a considerable amount of biomass are an appetizing food source for higher predators and help complete the energy flow in the ecosystem. The property with its excellent biodiversity of macrobenthos, therefore, is an optimal place for waterbirds as they can accumulate enough energy before flying to other locations. Macrobenthos in the property also maintain a rich fishery stock.

Table 2-5. Number of species of macrobenthic organisms present in the nominated property

Taxon	Nominated Property (%)		
	Soft Substrates (including salt marshes)	Rocky Habitats	Property Area
Annelida	204 (31.4)	18 (5.9)	212 (24.7)
Mollusca	201 (31.0)	137 (44.6)	297 (34.7)
Arthropoda	171 (26.4)	104 (33.9)	237 (27.7)
Echinodermata	23 (3.5)	9 (2.9)	30 (3.5)
Others	50 (7.7)	39 (12.7)	81 (9.5)
Sum	649 (100.0)	307 (100.0)	857 (100.0)

• Waterbirds

The total number of waterbirds and raptor species in the property tallies up to 277 (231 and 46 respectively). Including the 22 IUCN Red List species, the property is visited by over 300,000 migratory birds of 118 species (101 waterbirds and 17 raptor species). Among waterbirds (50 million individuals of 250 species) coming to the nominated property following the East Asian-Australasian Flyway, 33 species (13.2%) are either threatened or near-threatened species, which is the highest ratio among the flyways for migratory birds reported by IUCN in 2012. The property supports 22 species or 66.7% of them, showing how crucial this site is. It also has ample food for migratory birds such as polychaetes, amphipods, bivalves and Japanese mud crabs. Thus, the property plays a critical role as feeding and resting sites for migratory birds along the East Asian-Australasian Flyway.

Table 2-6. Annual diversity and population of migratory birds present in the nominated property

Year	2009	2010	2011	2012	2013	2014	2015	Max.
Number of Species	78	96	93	95	101	95	78	118
Population	87,089	132,395	182,022	144,230	198,306	142,478	152,620	302,465

Source: Korean Shorebirds Network Secretariat (2015)

Major dominant species in the nominated property include dunlins (26%) as well as bar-tailed godwits (10%) and great knots (9%), which all appear on the IUCN Red List. The property is essential for the survival of internationally protected species such as black-faced spoonbills, eastern curlews, Eurasian oystercatchers and Nordmann's greenshanks, all on the IUCN Red List. Dunlins, coming to the ROK during spring and fall, mainly feed on Yellow Sea sand snails, sand wormes and Japanese mud crabs that are abundant in the property. The arrival of dunlins corresponds to the period when the biomass of these food species grows higher helping to generate a perfect ecosystem process.

The property can serve as a substitute for previously damaged tidal flats nearby. After the Saemangeum reclamation, some waterbirds which lost their stopover sites began flying to the nearby Gochang or Seocheon Getbol (Figure 2-32). Thus, it is certain that the property is a reliable refuge for the biodiversity of endangered species. It is also the last remaining tidal flats as a feeding and resting site for the internationally protected species of waterbirds due to its high production and biodiversity.

Figure 2-32. Eurasian oystercatcher on Seocheon Getbol

• Fish

A total of 54 coastal fish species are caught in the property (Table 2-7). Among them, 29 species (54%) directly feed off benthic invertebrates in tidal flats and the remaining species also capitalize the tidal flats to some degree. However, the actual number of fish that preys upon benthic invertebrates on the tidal flats is far bigger.

Fish eat benthic diatoms with mud in the tidal flats or prey upon benthic invertebrates or small fishes. They are directly or indirectly relevant to the primary production in tidal flats and coastal zones. Top predators that feed off demersal mysids, shrimps, mantis shrimps, squids and polychaetes include bighead croakers (*Collichthys niveatus*), butter fish (*Pampus* spp.), rays and croakers (*Miichthys miiuy*).

The property’s outstanding primary production and abundant benthic invertebrates maintain vibrant coastal fisheries. Since the property’s coastal zones are used as feeding and breeding sites by fish and benthic invertebrates coming from the offshore, it contributes to combining all the marine ecosystems into a large single system.

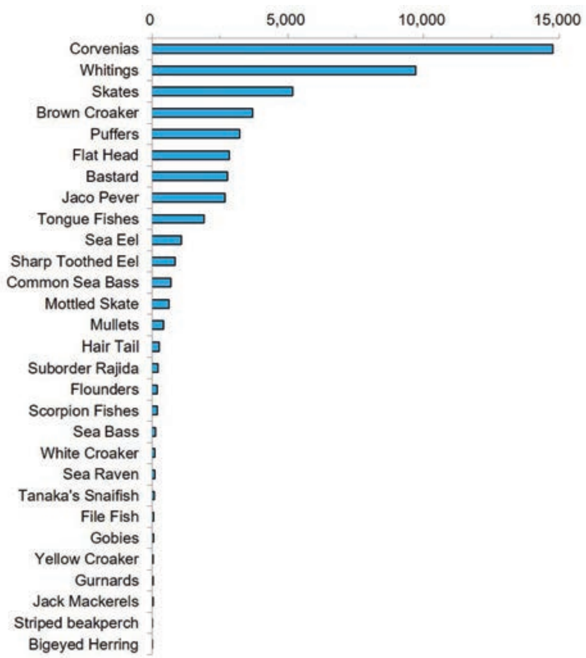


Figure 2-33. Total catch of fish feeding on benthic organisms in the nominated property from 2005 to 2015 (Unit: 1,000 ㎏)

Table 2-7. Number of fish species present in the nominated property from 2005 to 2015

Category	Coastal Fish Species	Demersal Fish Species
Seocheon	30	20
Gochang	46	27
Shinan	41	25
Boseong-Suncheon	44	26
Total	54	29

• Mammals

Coasts near Shinan Getbol are inhabited by finless porpoises (*Neophocaena phocaenoides*). They are listed as vulnerable IUCN Red List species and are commonly found within 3-5 ㎞ of coasts with a water depth of 20 to 50 m. It is reported that there are about 36,000 finless porpoises in the west coast of ROK and they directly and indirectly utilize the coastal ecosystem tidal flats. Terrestrial otters (*Lutra lutra*) also from time to time come down to salt marshes to feast on tidal organisms. Such feces of the otter have been found in many uninhabited islands (22.3% of total uninhabited islands) in Shinan Getbol not to mention near the other component. This exemplifies a close connection between the property and the neighboring coastal marine ecosystems, as well as the terrestrial ecosystems.

2.a.v.2 Endangered Species

The number of migratory birds living in the nominated property stands at over 300,000 of 118 different species (101 waterbirds and 17 raptor species), including 22 IUCN Red List birds. The East Asian-Australasian Flyway is used by 250 species of birds. It was reported by IUCN (2012) that the flyway also supports 33 (13.2%) threatened or near-threatened species out of the 250 species, which is the highest ratio among all the flyways for migratory birds. In 2015 alone, six additional waterbirds were newly listed as either a threatened or a near-threatened species. Unfortunately, waterbirds that rely heavily on the property have experienced a serious decrease in population (IUCN Resolution 26, WCC 2016). This paradoxically proves the critical role of the nominated property in offering shelters for waterbirds and other endangered species using the East Asian-Australasian Flyway. The property not only supports 101 species or 40.4% of the waterbirds out of the total 250 species that use the flyway but also supports 22 species or 66.7% of the total 33 endangered species.

It should be noted that the property is inhabited or stopped over by many internationally protected species on the IUCN Red List: endangered species (EN) such as black-faced spoonbills, Nordmann’s greenshanks, eastern curlews, oriental storks and great knots as well as vulnerable species (VU) including swan geese, pochards, Chinese egrets, white-naped cranes, hooded cranes and Saunders's gulls. The major species in the property are bar-tailed godwits (10%) and great knots (9%), which are known to travel the longest distances from Alaska to the non-breeding grounds in Australia and New Zealand.

These migratory shorebirds cannot survive the migration unless they have proper stopover sites for feeding and resting. A regrettable example is the case of the Saemangeum reclamation, where the global population of shorebirds was reduced by 20% upon the destruction of natural tidal flats. The property is one of the three East Asian-Australasian Flyway zones where the density of endangered shorebirds that demand priority protection is the highest. A total of 24 species out of 63 or 38% of shorebird species have been supported by the property.

Figure 2-34. Spoon-billed sandpiper, critically endangered species (CR) on the IUCN Red List

It has been shown that the nominated property is one of the most crucial sites on the flyway that supports the highest number of endangered species in the world. Every year on the Yubudo Island in Seocheon Getbol, 2 to 6 spoon-billed sandpipers, which are classified as a critically endangered species (CR) on the IUCN Red List, are observed (Figure 2-34). Their expected remaining population is only about 300 to 600 in total worldwide. This area also serves as the largest habitat in ROK for Eurasian oystercatchers, a near-threatened species (NT) on the IUCN Red List, with a maximum population of 6,000. In addition, the Yubudo Island is known as a core habitat for internationally protected waterbirds such as great knots (EN) and bar-tailed godwits (NT) on the IUCN Red List with maximum populations of about 15,000 and 20,000 respectively.

Moreover, eleven species such as eastern curlews, Eurasian oystercatchers, bar-tailed godwits and red-necked stints are observed throughout the property (Table 2-8). As for the eleven species, including spoon-billed sandpipers (CR) out of the 22 endangered waterbirds appearing in the property, more than 1% of the world's population has been observed in this area. These findings show how important the property is in terms of conservation of endangered species.

Along with waterbirds, the nominated property is also inhabited by endangered macrobenthos species. Convexed crabs (*Chasmagnathus convexus*), red mitten sesarmid crabs (*Sesarmops intermedius*) and Chinese midas-ear snails (*Ellobium chinense*) are found in salt marshes of the upper intertidal to supratidal flats, while neritid freshwater snails (*Clithon*

retropictus) live in the brackish water zone of streams flowing into the supratidal flats. Since these species can only live in limited habitats with specific conditions, protection for their habitats is absolutely needed.

Convexed crabs and red mitten sesarmid crabs can live only in common reed habitats. Chinese midas-ear snails live only in the community of reeds and seaside lawn grass. Neritid freshwater snails only inhabit brackish water zones of clean, small streams flowing into the tidal flats. Thus, their presence itself is a sign of well-preserved ecosystem of salt marshes in the nominated property.

Colonies of milky fiddler crabs (*Uca lactea*), indicators of healthy tidal flats, occur only in limited areas with high sand contents in upper intertidal to supratidal mud flats (Figure 2-35). For this reason, special care and protection should be in place so as not to cause any changes to their habitat due to the change of sedimentary environments.

Figure 2-35. Milky fiddler crab (*Uca lactea*), endangered species in the nominated property

Table 2-8. List of species and maximum observed population of waterbirds out of IUCN Red List (2009~2015)

IUCN Red List	Scientific Name	Common Name	Nominated Property					IUCN Red list	% of World total
			Seocheon	Gochang	Shinan	Boseong-Suncheon	subtotal	World total	
CR	*Eurynorhynchus pygmeus*	Spoon-billed Sandpiper	6	4	-	-	10	300-600	1.7
EN	*Calidris tenuirostris*	Great Knot	14,858	7,921	459	244	23,482	380,000	6.2
	Ciconia boyciana	Oriental Stork	-	5	-	-	5	3,000	0.2
	Numenius madagascariensis	Far Eastern Curlew	5,096	392	299	199	5,986	38,000	15.8
	Platalea minor	Black-faced Spoonbill	52	-	-	2	54	3,356	1.6
	Tringa guttifer	Spotted Greenshank	13	4	-	3	20	999	2.0
VU	*Anser cygnoides*	Swan Goose	1	-	-	15	16	90,000	0.0
	Aythya ferina	Common Pochard	-	15	70	1,945	2,030	570,000	0.4
	Egretta eulophotes	Chinese Egret	38	2	12	-	52	3,400	1.5
	Grus monacha	Hooded Crane	-	-	-	900	900	11,600	7.8
	Grus vipio	White-naped Crane	-	-	-	32	32	6,750	0.5
	Larus saundersi	Saunders's Gull	774	41	15	1,219	2,049	14,400	14.2
NT	*Anas falcata*	Falcated Duck	14	120	120	32	286	89,000	0.3
	Calidris canutus	Red Knot	114	19	9	152	294	979,000	0.0
	Calidris ferruginea	Curlew Sandpiper	4	1	-	3	8	1,285,000	0.0
	Calidris ruficollis	Red-necked Stint	2,183	563	1,770	85	4,601	315,000	1.5
	Haematopus ostralegus	Eurasian Oystercatcher	6,000	2,980	70	16	9,066	1,160,000	0.8
	Heteroscelus brevipes	Grey-tailed Tattler	154	670	215	673	1,712	44,000	3.9
	Limosa lapponica	Bar-tailed Godwit	20,014	536	2,581	1,678	24,809	1,149,000	2.2
	Limosa limosa	Black-tailed Godwit	1,050	40	101	729	1,920	809,000	0.2
	Numenius arquata	Eurasian Curlew	9,018	133	512	294	9,957	1,310,000	0.8
	Vanellus vanellus	Northern Lapwing	-	28	1	25	54	10,500,000	0.0
			17	18	14	19	22		

Source: Korean Shorebird Network Secretariat (2015) / National Institute of Biological Resources (2009-2015) / IUCN Homepage (2017)

2.a.v.3 Endemic Species

The number of animal species regarded as endemic species amounts to 285 of all the marine organisms in ROK and, among them, 47 species or 16.4% appear in the nominated property (Table 2-9). Among the 47 species, 24 species or 51% of the macrobenthos are endemic species that appear only in the property (Table 2-10).

These endemic species in the tidal flats are mostly new species recently identified. In particular, many of the newly added are endemic species from amphipods that have been subject to active taxonomic research. The number of endemic species will increase as new species are further identified through further research.

The Gochang Getbol is a habitat for tiger crabs (*Orithyia sinica*), a species endemic to the Yellow Sea, and has been reported to have only one species in a genus worldwide (Figure 2-36). Tiger crabs are 55 ㎜ wide and produce as many as 54,000 eggs, each 0.7 ㎜ in size. Local fishermen deploy traditional fishing techniques based on their indigenous knowledge to capture the crabs. The local community exercises tight self-imposed rules to control a total amount of its catch. Its hind legs at the very end are wide just like blue crabs, but they are not good swimmers. Instead, they have evolved as a tidal flat digger.

Endemic species such as *Grandifoxus cuspis* or *Haustorioides nesogenes* usually stay on sand flats and hatch their eggs in the brood pouch on their ventral part of body. Their juveniles thus do not go through a larval stage. Even though they are small in size and live on shallow sand near the surface, they are still an important source of food for waterbirds because of their dense population.

Figure 2-36. Tiger crab (*Orithyia sinica*), an endemic species in the Yellow Sea

Table 2-9. Number of marine endemic species in coastal area of ROK

Taxon	Republic of Korea	Nominated Property
Porifera	30	0
Cnidaria	23	0
Bryozoa	10	1
Annelida	6	4
Mollusca	4	2
Arthropoda	204	40
Echinodermata	2	0
Chordata	6	0
Total	285	47

Source: National Institute of Biological Resources, 2014 (Invertebrates) / National Environment Information Network System (Chordates)

Table 2-10. List of endemic marine species present or potentially present in the nominated property

No	Taxon	Seocheon	Gochang	Shinan	Boseong-Suncheon
Phylum Bryozoa					
1	*Parasmittina contrar*			○	
Phylum Annelida					
2	*Clymenella koreana*	○	○	○	
3	*Microclymene propecaudata*	○	○	○	
4	*Petaloproctus macrodentatus*	○	○	○	○
5	*Phyllodoce koreana*	○	○	○	○
Phylum Mollusca					
6	*Duplicaria koreana*	○	○		
7	*Tugalina (Scelidotoma) vadososinuata hoonsooi*			○	○
Phylum Arthropoda					
8	*Ampithoe koreana*			○	○
9	*Anthessius kimjensis*		○		
10	*Colobomatus floridus*			○	○
11	*Colobomatus orientalis*			○	○
12	*Conchyliurus dispar*	○	○	○	
13	*Critomolgus malmizalus*				○
14	*Critomolgus nudus*	○	○	○	
15	*Critomolgus vicinus*	○	○	○	○

No	Taxon	Seocheon	Gochang	Shinan	Boseong-Suncheon
16	*Cryptopontius dong*				○
17	*Diastylis koreana*	○	○	○	○
18	*Diastylis paratricinta*	○		○	
19	*Dimorphostylis namhaedoensis*			○	
20	*Enterophilus cercomegalus*	○	○	○	○
21	*Eohaustorius setulosus*			○	
22	*Haustorioides koreanus*			○	
23	*Haustorioides nesogenes*			○	
24	*Hemadona clavicrura*				○
25	*Hemicyclops nasutus*	○	○	○	
26	*Hemicyclops parilis*		○	○	○
27	*Hemicyclops saxatilis*		○		
28	*Hemicyclops ventriplanus*			○	○
29	*Herrmannella exigua*		○		
30	*Herrmannella soleni*		○		
31	*Lepeophtheirus gusevi*				○
32	*Lichomolgus similis*	○	○	○	
33	*Lutumidomus tertius*	○	○	○	
34	*Mandibulophoxus hongae*			○	
35	*Mandibulophoxus mai*	○	○	○	
36	*Membranobalanus koreanus*				○
37	*Monoculodes koreanus*	○		○	
38	*Nitokra koreanus*			○	
39	*Perioculodes seohae*			○	
40	*Presynaptiphilus minutus*	○	○	○	○
41	*Protomolgus singularis*			○	○
42	*Rhodinicola laticauda*	○	○	○	
43	*Sinoediceros hwanghaensis*			○	
44	*Synaptiphilus longicaudus*	○	○	○	○
45	*Synchelidium trioostegitum*			○	
46	*Synstellicola paracarens*		○		
47	*Triacanthus luteus*				○
Total number of species		19	23	35	20

Source: National Institute of Biological Resources, https://www.nibr.go.kr

2.a.v.4 Harmony between Nature and Human Activities

The nominated property, Getbol, is an exceptional case because it displays a close relationship among different criteria for World Natural Heritage. The property is influenced by a very unusual tidal system and contains what is by international standards a usually diverse ecosystem. The main contributing elements can be summarized as follows:

1) The Yellow Sea is a wide epicontiental sea with an average depth of 50 m on an extensive continental shelf created by special geological conditions;

2) The irregular terrain has been created by tectonic forces as the area is adjacent to a subduction zone, and numerous islands and a complicate coastlines are partly a consequence of processes associated with changing sea level as climate changed in the past;

3) The nominated area experiences the highest tidal range observed in the Yellow Sea;

4) The seas around the nominated area receive abundant and nutrient-rich terrigenous sediments supplied by abundant runoff in warm temperate regime strongly influenced by continental monsoon climate.

The islands and coasts associated with the nominated property host diverse sedimentation environments with high geodiversity. In the coastal environment with its diverse mixture of sand, mud and mixed sediments, each with different density and porosity characteristics makes for tidal flats with diverse habitats and high biodiversity, this being further enhanced by the complex ecosystems of neighboring rocky shores.

Thus, the nominated property is an outstanding example displaying the interrelationships between geodiversity and biodiversity with the geodiversity directly influencing organisms, their habitats, and productivity along both tidal flats and rocky shores.

The vast organic-rich tidal flats have also provided an important stopover site for migratory birds on their annual migrations. It is interesting to observe that different birds visit different parts of the tidal flats according to the substrate type (grain size) and its composition, which again testifies to the strong linkages between water bird habitats and geodiversity.

As the sea level rose and began to intrude and form tidal flats from ancient times, humans gained food from the tidal flats. Shell mounds found in different locations along the coast provide evidence that fishing activities have taken place in the tidal flats for thousands of years. The tidal-flats monitoring results show that traditional fishing activities have successfully maintained the tidal flat ecosystem in a balance that includes human processes.

Figure 2-37. The nominated property as a unique example showing interconnected geodiversity, biodiversity and even cultural diversity

This example shows the traditional place of Man as part of the ecosystem, and the Republic of Korea government is determined to maintain a level of human resource use that continues to be sustainable and to exclude non-sustainable activities. Getbol, Korean Tidal Flat shows a high biodiversity based on the geodiversity of the tidal flats, and human activities relying on the biodiversity have become an integral part of a natural and healthy ecosystem.

2.a.vi Features of Each Serial Site

The four components of the nominated property display typical, but distinctive geological and geomorphological biological and ecological features of Getbol, and contribute to the overall value of the property. The significant values of each component are explained as follows.

Seocheon Getbol is a relatively small-sized island-type (archipelagic) tidal flat made up of 15 islands. As an estuarine type, located near the Yubudo Island of the Geumgang River estuary, Seocheon Getbol is a Type C in terms of the formation of the thick mud-flat sequences (Figure 2-17). Suspended sediments from Geumgang River and the mud sediments transported from offshore by the tidal currents converge near Yubudo Island and its surrounding islands. Geumgang River is an important source of all sediments, not only to Seocheon Getbol, but to the entire nominated property, as it provides rich nutrients. As a result, Seocheon Getbol area has the highest primary production among all the serial sites of the property, even to impact on the other three areas. Seocheon Getbol also sees the highest number of endangered migratory birds among the serial sites. About 147,000 waterbirds of 85 species, including 17 species on the IUCN

Red List, visit Seocheon Getbol. Yubudo Island, in particular, is the largest habitat for Eurasian oystercatcher (*Haematopus ostralegus*) in ROK and as many as 35,000 great knots and bar-tailed godwits (*Limosa lapponica*) visit the islands. Furthermore, the Seocheon Getbol supports 24 species (38 %) of 63 shorebird species that travel along the East Asian-Australasian Flyway.

Gochang Getbol is a typical open-embayed type tidal flat (macrotidal range about 7.2 m) and has developed in both the inner and outer sides of Gomsoman Bay. As a Type D in terms of the formation of the thick mud-flat sequences (Figure 2-17), Gochang Getbol currently has eight islands and some rocks exposed above the tidal flats, while many more islands are buried below the mud sediments. With the seasonal changes in dynamics of tide and wave, Gochang Getbol shows distinctive patterns of surface sediment distribution. This provides a unique habitat distribution pattern for living organisms. The location and the distribution of the sand flats and mixed flats in Gochang Getbol change in different seasons. Among the serial sites, Gochang Getbol is a representative site that shows the most dynamic and remarkable changes of sedimentary patterns as a result of the East Asian monsoon climate. Gochang Getbol hosts as many as 18 waterbird species on the IUCN Red List. Spoon-billed sandpipers, a critically endangered species (CR), are observed in this area. A total of 255 species of macrobenthos is also present in the property. Importantly, oriental storks (EN) appear only in Gochang Getbol among the serial nominated sites for feeding on Japanese mud crabs and gobies in fall to get through winter. Gochang Getbol is a habitat for tiger crabs, an endemic species to the Yellow Sea, and is reported to be a monospecific genus worldwide.

Shinan Getbol, representing the archipelagic type, is located near the coast surrounded by some over 850 islands. Shinan Getbol is a Type A in terms of the formation of the thick mud-flat sequences (Figure 2-17). The region demonstrates typical island-type (archipelagic) tidal flats with distinctive geological and geomorphological features as well as diverse habitats. The tidal currents run with vigor with a macrotidal range through the numerous islands, demonstrating the typical features of island-type tidal flats. Shinan Getbol also has broad tidal flats and deep tidal channels in between the islands. The overall sedimentary pattern demonstrates a high level of geodiversity and an associated complex ecosystem. The mud octopuses, found abundantly in this area, clearly show the evolutionary process operating within the mud flats ecosystem.

Boseong-Suncheon Getbol is a semi-enclosed Type B in terms of the formation of the thick mud-flat sequences (Figure 2-17). The tidal currents that run counterclockwise inside the relatively large Yeojaman Bay help to create a unique shape of tidal flats around the 20 islands that surround Jangdo Island. Deep channels run between the islands. The river that discharges into this area is small and so the amount of sediment supplied is not large enough to form an estuarine tidal flat. However, the suspended sediments that are carried in by the tidal currents from the outer seas of Yeojaman Bay accumulate around the islands and contribute significantly to the formation of the tidal flats. So, the Boseong-Suncheon Getbol area is a sink where the tidal flats sediments finally settle, having first started their journey in Geumgang River. The area has developed wide salt marshes and an active halophyte community. This site exemplifies the

survival pattern of halophytes at the point where river water flows into the sea. The area is also the largest winter stopover site for hooded cranes (VU).

Table 2-11. Various features of each serial property and their distinctions

Category		Seocheon Getbol	Gochang Getbol	Shinan Getbol	Boseong-Suncheon Getbol
Geological, geomorpho-logical features	Complexity level of sedimentation system	Very complex (estuary, waves, high waves, macrotidal range)	Complex (Open bay, high waves, macrotidal range)	Very complex (many islands, waves, High waves, macrotidal range)	Complex (semi-enclosed tidal flat bay, macro and mesotidal range)
	Number of Island	15	8	857	20
	Thickness of mud flats	Thick (> 6 m)	Very thick (> 20 m)	Very thick (> 25 m)	Thick (> 4 m)
	Type of Getbol	Estuarine	Open-embayed	Archipelago	Semi-enclosed
	Formation results of Getbol sequence	Type C	Type D	Type A	Type B
Biological and ecological features	Primary production (Chlorophyll-*a*, ㎎/㎡)	Very High (Average 81.0)	Very High (Average 67.6)	Very High (Average 52.2)	Very High (Average 66.8)
	Featured communities of organisms	Very well developed (Benthic diatoms, clams, gastropods, polychaete worms, amphipods, waterbirds)	Very well developed (Japanese mud crabs, sand crab, polychaete worms, surf clams, waterbirds)	Very well developed (clams, polychaete worms, amphipods, Japanese mud crabs, sand crab, mud octopus waterbirds)	Very well developed (Japanese mud crabs, cleistostoma dilatatum, polychaete worms waterbirds, halophytes)
	Multi-faced ecosystem	Excellent (mud-rock, sand-rock)	Excellent (mud-sand-rock-salt marsh)	Excellent (mud-rock, sand-rock)	Excellent (mud-rock, mud-salt marsh)
Biological and ecological features	Species diversity	Very High (Benthic diatoms 181 species algae 49 species, macrobenthos 181 species, waterbirds 85 species)	Very High (Benthic diatoms 194 species algae 9 species, macrobenthos 255 species, waterbirds 90 species)	Very High (Benthic diatoms 224 species algae 144 species, macrobenthos 568 species, waterbirds 90 species)	Very High (Benthic diatoms 188 species algae 23 species, macrobenthos 445 species, waterbirds 99 species)
	Supporting endangered species and endemic species	Very High (IUCN Red List 17 species spoon-billed sandpiper included)	Very High (IUCN Red List 18 species spoon-billed sandpiper and oriental white stork included/endemic species tiger crab)	Very High (IUCN Red List 14 species)	Very High (IUCN Red List 19 species Hooded cranes included)

2.a.vi.1 Seocheon Getbol

• Geological and Geomorphological Features

Distribution of Tidal Flats and Tidal Channels

Two big tidal channels are located in the east and north of Seocheon Getbol. The eastern tidal channel, connected directly to Geumgang River, serves as the main tidal channel. A river-mouth dam in Geumgang River blocks freshwater from flowing out continuously. However, on average, its flood gates open about 10 times a month to adjust the level of freshwater in order to manage flood prevention. Therefore, freshwater from Geumgang River and suspended sediment are released when the gates open. During the rainy season in summer, all flood gates are open to discharge freshwater, thereby supplying a huge volume of suspended sediment to the estuary. With the aid of tidal currents, the discharged suspended sediments flow into Seocheon Getbol, as well as to the other nominated sites, playing an important role in forming the mud flats.

The northern tidal channel (called 'Gaeya' tidal channel) is gradually becoming shallower due to the decreased speed of the tidal current caused by the river-mouth dam on Geumgang River. Therefore, the tidal channel in the north plays a lesser role in the movement and spread of sediments. This phenomenon contributes to expanding the tidal flats on the Yubudo Island and the tidal flat on the northeastern part of property. It also causes fine-grained sedimentation in the subtidal area and lower intertidal flats.

Surface Sediments and Seasonal Changes

Among the components, Seocheon Getbol is the first tidal flat where sediment from Geumgang River is accumulated. It is also strongly affected by waves from the west coast. This wave energy explains why tidal flats around the coast in this region are mostly sand flats with the exception of tidal flats on the inner parts surrounded by islands where the protection reduces wave energy.

During summer, surface sediments of Seocheon Getbol are composed mainly of medium to very fine sand and silt with about 10% clay. Sand sediment tends to decrease toward the east from the west of Yubudo Island. Sediment distribution changes dramatically in the east and west sides due to splitting by bars and spits connected to the west of Yubudo Island. Mud flats are widespread in the inner area between Yubudo Island and Daejukdo Island. Mud facies are dominant in the eastern part of the bars and spits, whereas sand facies are observed in a narrow eastern zone along the main tidal channel where tidal current is rapid. In the western intertidal area, sand and muddy sand facies prevail. These facies show a repetitive strip pattern as muddy sediments accumulate in the troughs between swash bars developed in the sandy intertidal area.

A number of spits have formed in the northwest of the Yubudo Island tidal flat (Figure 2-42). Sandy mud facies are observed along the lower shore-face of the spits, implying that the pre-existing mudflat sediments are eroded and replaced by present sand sediment. A training

dike is located in the southwestern part of Yubudo Island. In the case of mud flats adjacent to the training dike, mud-dominant sedimentary facies are mainly formed, because the inflow and outflow of sediment is limited due to the dike. The dike, together with small islands, protects the western side from waves, creating a lower energy environment there and limiting the movement of sandy sediment. Tidal flats located on the western coast of Yubudo Island show weak seasonal changes. There, sand flats and sand spits are dominant during winter. In contrast, a little muddy sediment covers the top of sand flats during summer.

Surface sediments in Seocheon Getbol during winter show similar sedimentary facies patterns to those observed in summer (Figure 2-38). However, mud flats decrease in distribution or occur partly on sand flats. In the western and northern sandy intertidal areas of Yubudo Island, muddy sand facies are repeatedly distributed in parallel with sand bars during summer. In winter, however, muddy sand facies are rarely observed. In the tidal flats on the easternmost side along the margin of tidal channel, mud and sandy mud facies prevail, and sand facies occur only in summer. In winter, sand facies are widely distributed in the northern area, showing diminishing mud and sandy mud facies in distribution.

The seasonal changes result from the heavier influence from waves in winter than in summer. In winter, sand sediments are dominant in the western intertidal area facing the open sea. The northern parts of the easternmost intertidal area are also greatly affected by waves, which contribute to a wider area of sand sediment. During summer, weaker waves and relatively stronger tidal currents lead sand sediments to flow deep in the tidal channels of Geumgang River.

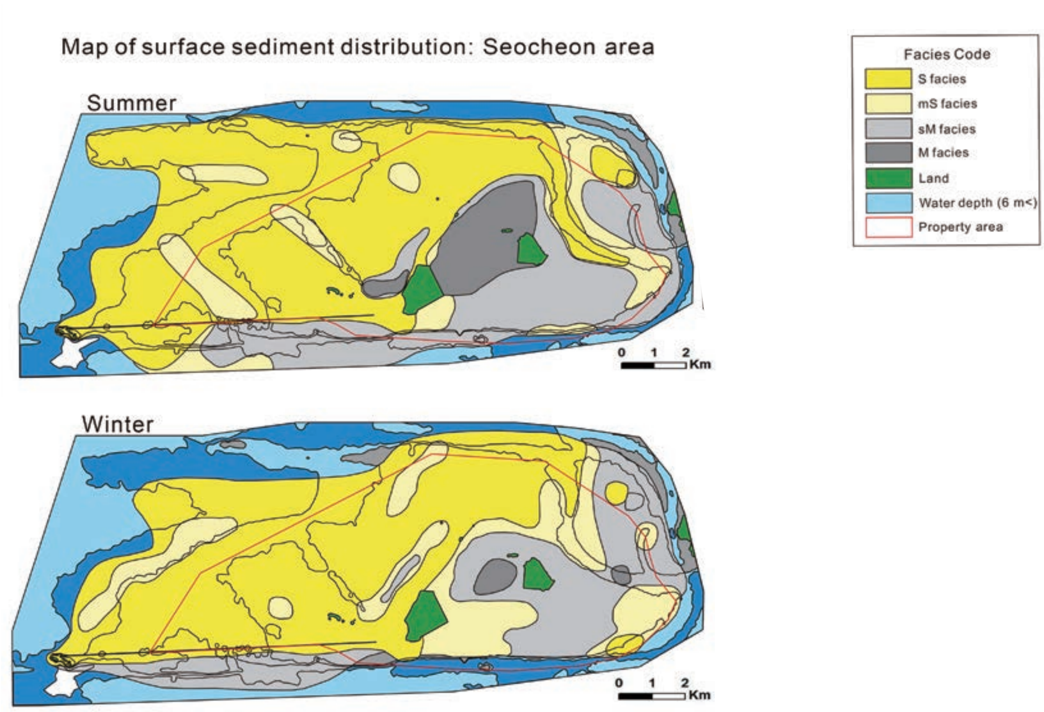


Figure 2-38. Seasonal changes of tidal-flat surface sediment in Seocheon Getbol

Basement Rocks and Holocene Tidal Flat Sequences

Before there was a significant cover of tidal sediments in this area, Seocheon Getbol was a small-sized archipelagic feature with more islands than at present. Judging by the depth to the basement rocks, the thickness of the Holocene sedimentary deposits may range from 10 to 15 ㎙, although this may include some Pleistocene tidal-flat sediment. The inner tidal flats surrounded by islands are all mud flats thicker than 6 ㎙ as confirmed by vibra cores. However, it is expected that there could be even deeper mud flats formed in the pre-existing tidal channel between Yubudo and Daejukdo islands (Figure 2-41).

Individual Component of Sedimentary Subenvironment

Mud flats: Wide mud flats are formed in the southeastern part of Seocheon Getbol. The mud flats are located near the estuary of Geumgang River where abundant amounts of suspended sediment have been supplied. Most suspended sediments are delivered to the outer part by the combined strong current of ebbing tidal and river flows, but they can be returned to the estuary again by flood tide currents. Since islands were formed where these sediments could accumulate, the sedimentation rate is very high (4.8-7.3 ㎜/yr). Also, the top surface level of the mud flats on Yubudo Island is relatively high due to a high sedimentation rate, which leads to limited development of tidal gullies compared to other components of the nominated property. Mud flats on the east side near to the estuary of Geumgang River have relatively high sand content, although on the north side the mud flats contain much less sand. The amount of sand incorporated in mud flat sediments varies by season; generally, sand content is higher in winter.

Figure 2-39. A scenery of Yubudo Island intertidal flat in the Seocheon Getbol from the south.
Wide mud flats are distributed in the inner part which are surrounded by spits and small islands.

-20 m of mean sea level

-10 m of mean sea level

The present

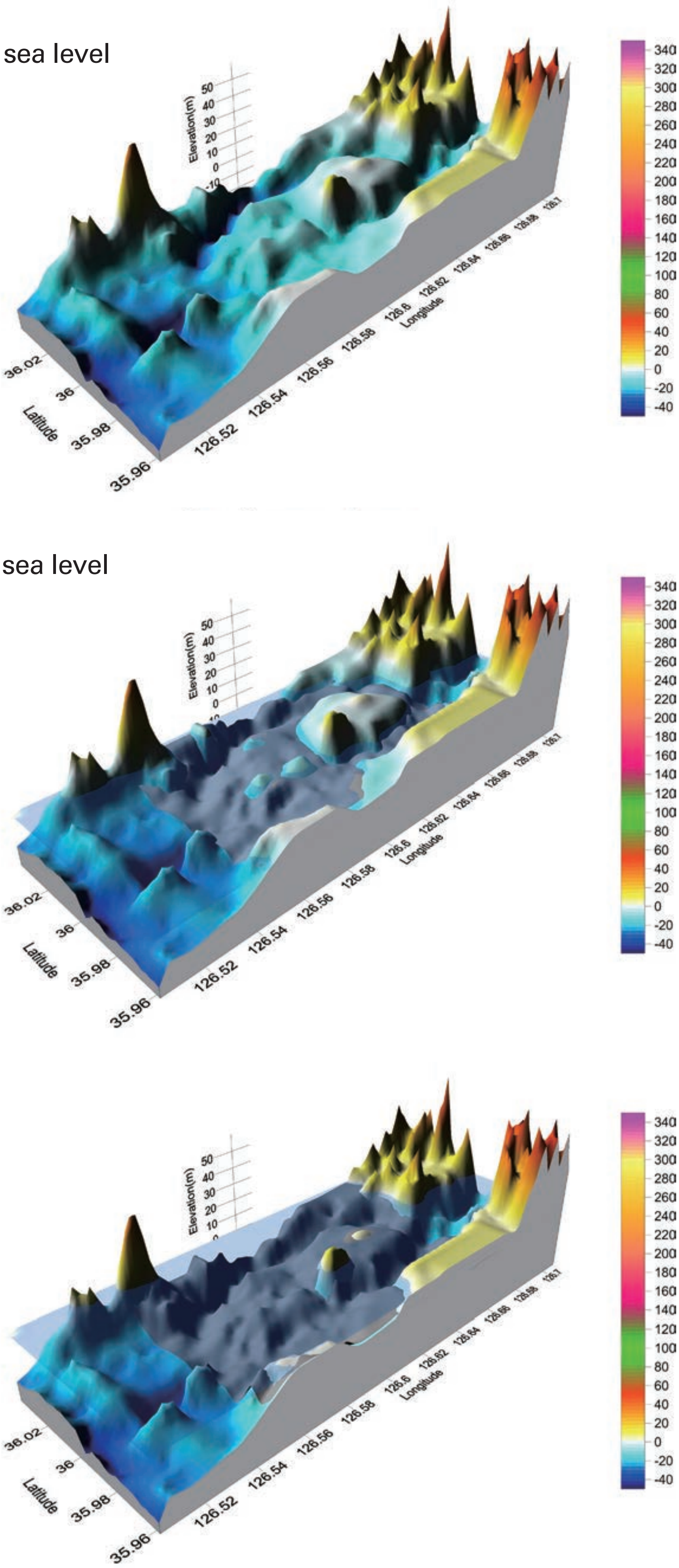


Figure 2-40. Paleo-bathymetry based on acoustic basement in the Seocheon Getbol, showing the formation of tidal-flat sequences and some islands covered by mud flats according to sea levels of -20 m, -10 m and the present

Sand flats and spits: Sand flats usually formed on the west and northwest coasts which are affected mainly by waves. During winter, the flats are wave-dominated, therefore, the formation and movement of swash bars is easily observed. But in summer, some parts of the sand flats are covered with mud flats. On the north side of Seocheon Getbol, islands are connected to each other by narrow spits. During winter, the spits become connected to multiple swash bars and form wide sand flats. Narrow spits are also observed during summer along the connected islands. They contribute to providing suitable sedimentary environments where migratory birds can feed and rest safely.

Sand dunes and salt marshes: Narrow belts of sand dunes and salt marshes have formed on the west side of Seocheon Getbol. A small salt marsh is present behind the sand dunes. Another relatively large salt marsh formed in an artificial, abandoned saltpan.

Figure 2-41. Depositional Components formed in Seocheon Getbol

Thick Mud-flat Sequences

The western and eastern intertidal areas of Yubudo Island clearly show different vertical sedimentary sequences. In the western area, a coarsening-upward trend is dominant, whereas fining-upward trend is observed in the eastern area. Mixed flats are dominant in the lower part of the western intertidal area and sand facies become prevalent toward the upper part. At the uppermost parts of the intertidal sequences formed near the rocky island in the north, the sedimentary layers of sand bars or spits are present in the subsurface. Mixed flat facies are observed at the lower part of the eastern intertidal area of Yubudo Island, and muddy intertidal facies dominate towards the top. Coarse-grained sediments are intercalated in the muddy layers at the top; these sediments having been washed over from sand bars and spits in the north during winter windstorms or summer typhoons. In the inner part of intertidal area, where wave energy coming from the open sea is blocked by the rocky islands and sand bars, muddy sediments have been vertically aggraded in a stable manner over an extended time period. This shows that sandflat sediments already covered some rocky islands during transgression. Interestingly, landward-prograding transgressive sand sequences borders with mud flat deposits in the inner sides of the archipelago.

Figure 2-42. A scenery of the northern Yubudo Island intertidal flat in Seocheon Getbol showing multiple swash bars and spits connected with islands. These are mostly used by migratory waterbirds as places for feeding and resting.

For the formation of the thick mud-flat sequences, Seocheon Getbol represents an example where mud flats start to be covered with sand flats as sea level rises. A large amount of sediment flows out from the estuary and comes back again, being driven by tidal currents that start to cover most islands and penetrate tidal channels. The sandy sedimentary layers have

already started to move from the outer sides into the inner side of the islands. If sea level continues to rise, the physiographical features of this island with tidal flats may be slightly changed into a sand ridge, but a fixed or stable one, not involving moving sand islands like barrier islands, which are common in Wadden Sea and along the eastern coast of U.S.A.

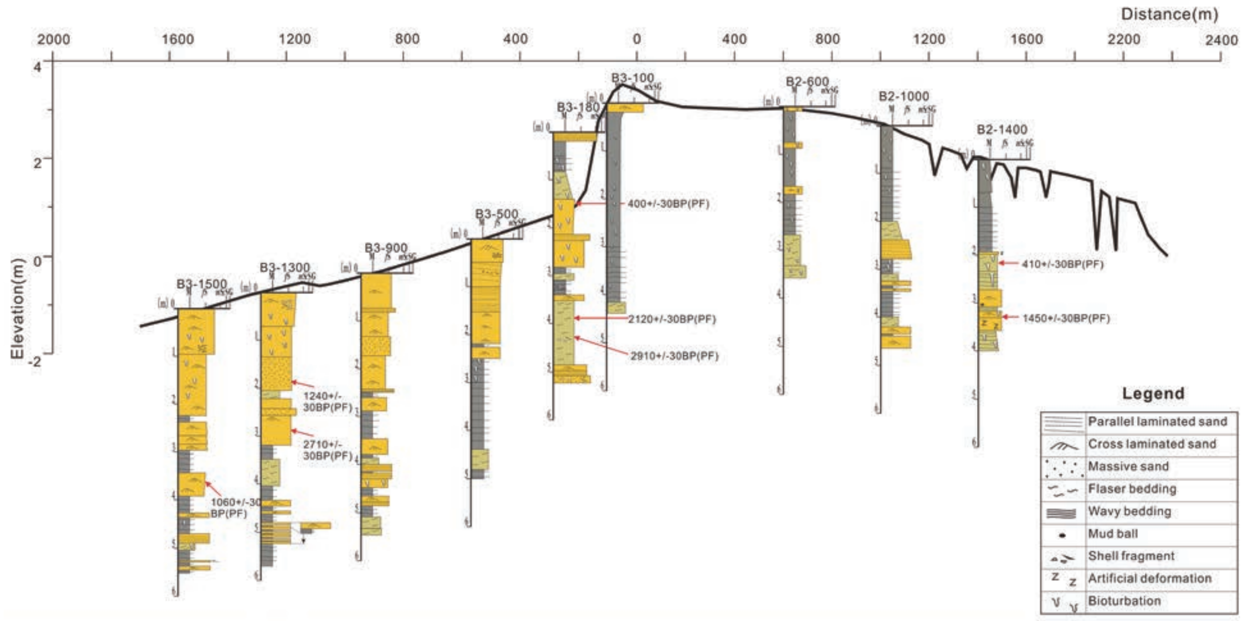


Figure 2-43. Holocene sedimentary sequences across the Yubudo Island tidal flat in Seocheon Getbol based on core data

• Biological and Ecological Features

Various Habitats and Community Evolution

Seocheon Getbol is characterized by mud flats in the central area surrounded by small islands where wave energy is low, but also by sand flats toward the offshore with high wave energy. Rocky habitats lie between these two flats, which provide Seocheon Getbol with a comprehensive coastal ecosystem containing all the different types of habitats.

One of the most distinctive features of Seocheon Getbol is the communities of hard clam, surf clam, Yellow Sea sand snail and polychaetes, and of the waterbirds that prey on them. At the early stage of tidal flat formation, benthic diatoms (primary producers) were a flagship species of the initial mud flat. As sand flats started to be developed, the communities of clams, gastropods, polychaetes and amphipods in a planktonic larval stage have settled in. Since then, the communities have evolved into their present forms where waterbirds preying on them serve as a keystone species. Such community evolution indicates that a complete ecological process is at work starting from primary producers through benthic organisms and to waterbirds which are the top consumers.

Narrow salt marshes of East Asian seepweed (*Suaeda japonica*) are formed in upper intertidal to supratidal mud flats on Yubudo Island. The landward side of the sand flats has sand dunes which provide more variety of habitat. The salt marshes and sand dunes also contribute a connection between terrestrial and marine ecosystems.

Training dikes have been constructed to block sediments from flowing into the commercial sea routes of Gunsan Port at the estuary of Geumgang River. These dikes play an important role in keeping Seocheon Getbol healthy by blocking contaminated fine-grained sediments from flowing into the tidal flats. Pollution indicators such as two bivalve species are observed in muddy sediments offshore at the outer side of the dikes. However, such indicators do not appear in Seocheon Getbol, which means that Seocheon Getbol remains unaffected.

Biodiversity and Endangered Species

Benthic diatom and primary production

About 181 species of benthic diatoms are observed in mud and sand flats of Seocheon Getbol. Dominant species include pennate diatoms (*Paralia sulcata, Amphora holsatica* and *Navicula* sp.). The measured value of Chlorophyll-*a*, an indicator showing primary production, ranges from 33.2-81.0 ㎎/㎡ on average. The primary production supports a high secondary production of macrobenthos such as filter feeding clams and deposit feeding polychaetes. The primary production supports a high secondary production of macrobenthos including filter feeding clams and deposit feeding polychaetes.

Macrobenthos

High levels of primary production and habitat diversity indicate that Seocheon Getbol provides a good environment for macrobenthos. The 181 species present constitute an average density and biomass of 1,736 individuals/㎡ and 442.2 g/㎡, respectively. Surf clams, hen clams, polychaetes with high biomass, and amphipods with low biomass are dominant in this area. They fall prey to waterbirds coming to Seocheon Getbol, thereby facilitating the development of a community where waterbirds have become a keystone species. Because clams such as surf clam, corbulid bivalve and hard clam are found in high density and are suspension feeder (Table 2-12), high primary production in tidal flats and pelagic ecosystem are significantly responsible for the growth and reproduction of these species. The growth and reproduction of the snails, such as Yellow Sea sand snails, are also affected by the primary production in the tidal flats even though they are deposit feeders. Thus, the snails also contribute to the overall energy cycle process. Certain fish come back to tidal areas during flood tides. For those fish, including gobies, high primary production is also a key condition for their good feeding site and nursery ground. Tidal flat organisms directly or indirectly utilize the tidal flats for their livelihood; thus contributing to completing an ecosystem stretching from the coast out to the open sea.

Table 2-12. Dominant species of macrobenthos present in Seocheon Getbol. Only the species higher than 1% in abundance are indicated.

Scientific name	Common name	Taxon	Mean density (ind./㎡)	%
Mactra veneriformis	surf clam	Bivalvia	779±105	31.7
Potamocorbula amurensis	corbulid bivalve	Bivalvia	304±84	12.4
Umbonium thomasi	Yellow Sea sand snail	Gastropoda	277±58	11.3
Mactra chinensis	hen clam	Bivalvia	270±95	11.0
Heteromastus filiformis	capitellid polychaete	Polychaeta	81±13	3.3
Nephtys californiensis	nephtyid polychaete	Polychaeta	56±7	2.3
Mandibulophoxus mai	phoxocephalid amphipod	Amphipoda	55±12	2.3
Lagis bocki	bock's pectinated-worm	Polychaeta	44±9	1.8
Monoculodes koreanus	oedicerotid amphipod	Amphipoda	41±8	1.7

Waterbirds

Compared to other components of the serial nominated sites, Seocheon Getbol supports the largest number of species and population of waterbirds. A total of 147,000 waterbirds from 85 species, including 17 species on the IUCN Red List, visit Seocheon Getbol. Yubudo Island is the largest habitat for Eurasian oystercatcher in ROK and as many as 35,000 great knots and bar-tailed godwit make appearances on the island (Figure 2-44). Furthermore, Seocheon Getbol hosts 24 species (38%) of 63 shorebird species that travel along the East Asia-Australasian Flyway. This is attributed to the high density benthic organisms with high biomass that the waterbirds can feed on.

Figure 2-44. Eurasian oystercatcher, keystone species and NT on IUCN Red List, flying up after resting and feeding in Seocheon Getbol

Endangered species

Notably spoon-billed sandpipers, a critically endangered species (CR), are crucial visitors to Seocheon Getbol (Figure 2-45). The entire global population of this species is about 300 to 600. From 2009 to 2015, 2 to 6 of them appeared on Yubudo Island. Spoon-billed sandpiper feed on polychaetes, crabs and gastropods. High primary production and abundant prey on Yubudo Island has led this species to appear on the site. Therefore, it is very important to protect this stopover site for spoon-billed sandpipers and to increase the population of the species.

Seocheon Getbol is also the largest habitat for Eurasian oystercatchers in the ROK. As many as 6,000 of them appeared from 2009 to 2015; recently the number rose to 11,000. About 15,000 great knots and 20,000 bar-tailed godwits also visit the tidal flat. A population of 178,279 from 24 shorebird species out of 63 species coming to the whole tidal flats in the ROK are observed, which means Seocheon Getbol supports 38% of the total shorebirds.

Figure 2-45. Spoon-billed sandpiper (*Eurynorhynchus pygmeus*) in Seocheon Getbol

2.a.vi.2 Gochang Getbol

• Geological and Geomorphological Features

Tidal Channels

Along the southward coast of the bay mouth, narrow sand tidal flats and sand dunes are developed. A deep (about 15 m) main tidal channel has been formed along the northern rocky cliff of the bay, running from east to west. The velocity of the tidal currents in the center of the

tidal channel is 115 ㎝/s at spring tide and 150 ㎝/s at ebb tide, showing that the ebb current is stronger. However, the sedimentary structures in the depositional bodies indicate much stronger flood currents than ebb currents on the intertidal flat. Another two small tidal channels are formed on its southern and eastern coasts, which are connected to small streams and so form small estuarine tidal flats. However, their sediment supply is very small, not enough to support the historical formation of Gochang Getbol.

Surface Sediment and Seasonal Changes

Suspended sediments flowing in from Geumgang River in the north move to the south and are temporarily deposited on the upper intertidal flats during summer. In winter, those sediments are eroded and moved further down to the south by longshore currents. In this process, the bay-mouth area of Gochang Getbol serves as a temporary deposition site for fine-grained sediments coming to Shinan Getbol. Some suspended sediments are transported inside the bay, forming a typical embayed mud-flat sequence.

Sand flats, mixed flats composed of silty sand and sandy silt, and mud flats gradually spread from the outer to inner part of Gomsoman Bay. Thus, surface sediments in Gochang Getbol become finer toward the inner part of the bay; a typical characteristic of an embayed tidal flat. However, such a general distribution pattern of surface sediments tends to be changed every year due to seasonal changes such as strong wave energy in winter and typhoons in summer.

Since Gochang Getbol is located on an open coast, it is greatly affected by the continental monsoon. Therefore, distinctive seasonal changes in tidal flat sediments are clearly observed in the outer part. Due to such climatic and oceanographic conditions, the seasonal changes in tidal flat sediments, from sand flats to mud flats, can be seen.

In summer, mud facies are observed partly in the front and back of Daejukdo and Sojukdo islands in the outer part of Gochang Getbol. But overall sand and mixed flats of silty sand are generally dominant. Mud flats are predominant in the central and inner parts of the bay. However, on the west side of a small stream at the center, coarse-grained sediments are more common. Sediments here also become finer toward the coast. In winter, most mud facies partially accumulated in the outer part during summer are eroded by the strong waves and flow out to the offshore, changing the surface to sand facies. The overall surface sediments continue to become finer toward the inner part of the bay in winter. On the other hand, mud facies located in the east side of the stream at the center rarely change even in winter.

About 5 to 10 ㎝ of mudflat deposits are eroded during winter. Sand flats in the outer part tend to be eroded by more than 20 ㎝ in thickness and accumulate again later. The outer part of Gochang Getbol is exposed to 10 wind storms in average per month during winter. This is why the most preserved sand-flat sequences of Gochang Getbol show sedimentary structure formed by strong storm or rapid tidal currents.

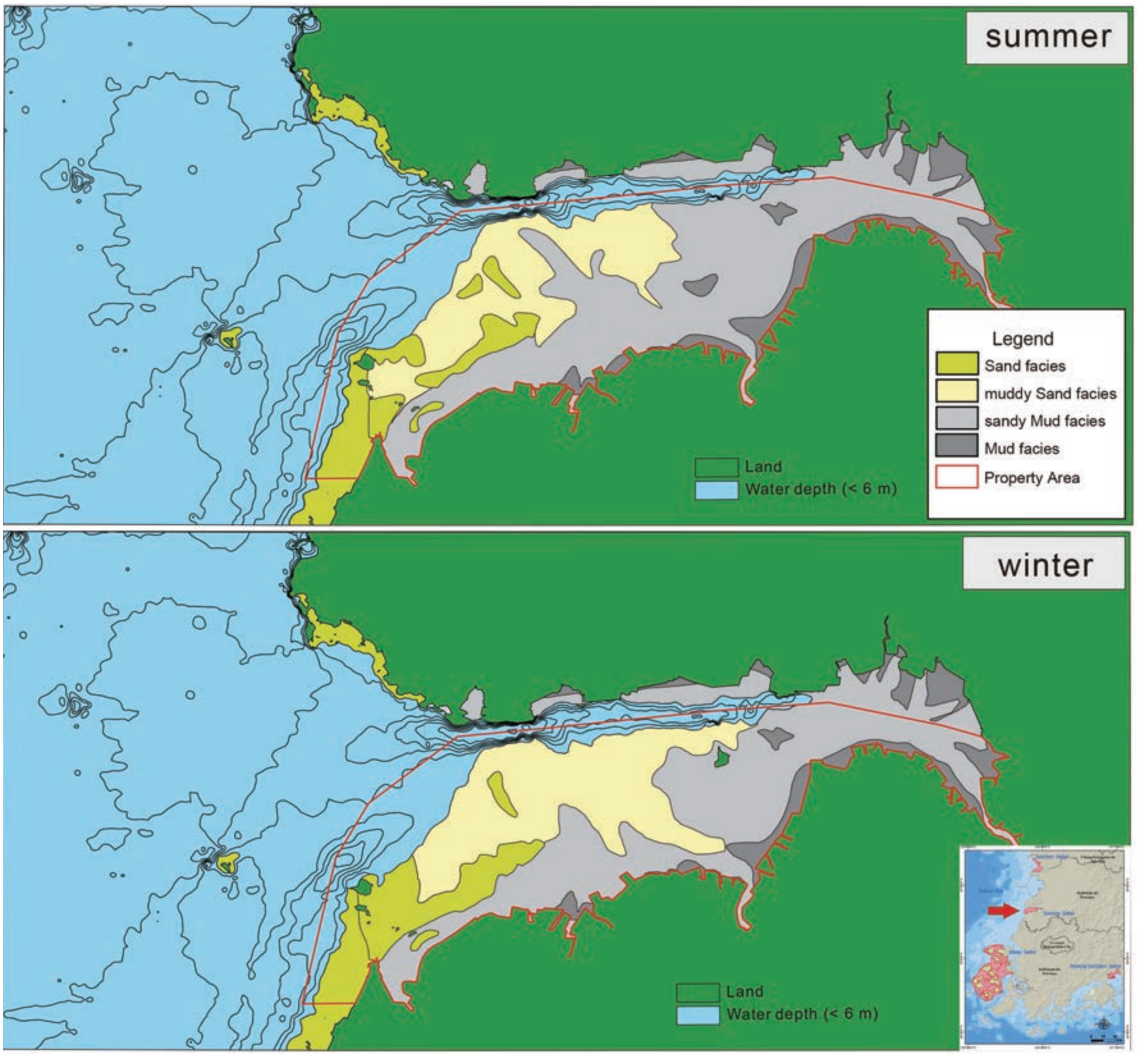


Figure 2-46. Seasonal Changes of tidal-flat surface sediment in Gochang Getbol

Basement Rocks and Holocene Tidal Flat Sequences

Quite a large number of small islands and rocks are found in the subsurface sedimentary layer of the subtidal area. An isopach map of basement rocks indicates that Daejukdo Island and other islands in the outer part of Gochang coast have blocked the wave energy induced by the northwesterly monsoon, enabling muddy sediments to be deposited in the sheltered rear of these islands.

About 9,000 years ago, when the sea level was 20 m lower than it is today, dozens of islands were present at the mouth of Gomsoman Bay, forming an archipelago. Mud flats more than 20 m deep had been deposited in pre-existing tidal channels inside the islands. As sea level began to rise to near its present position, sand flats started to cover the mud flats in the outer parts. After that time, the fine-grained sediments were supplied to the inner parts of the bay, forming wide inner mud flats on the bay-head area.

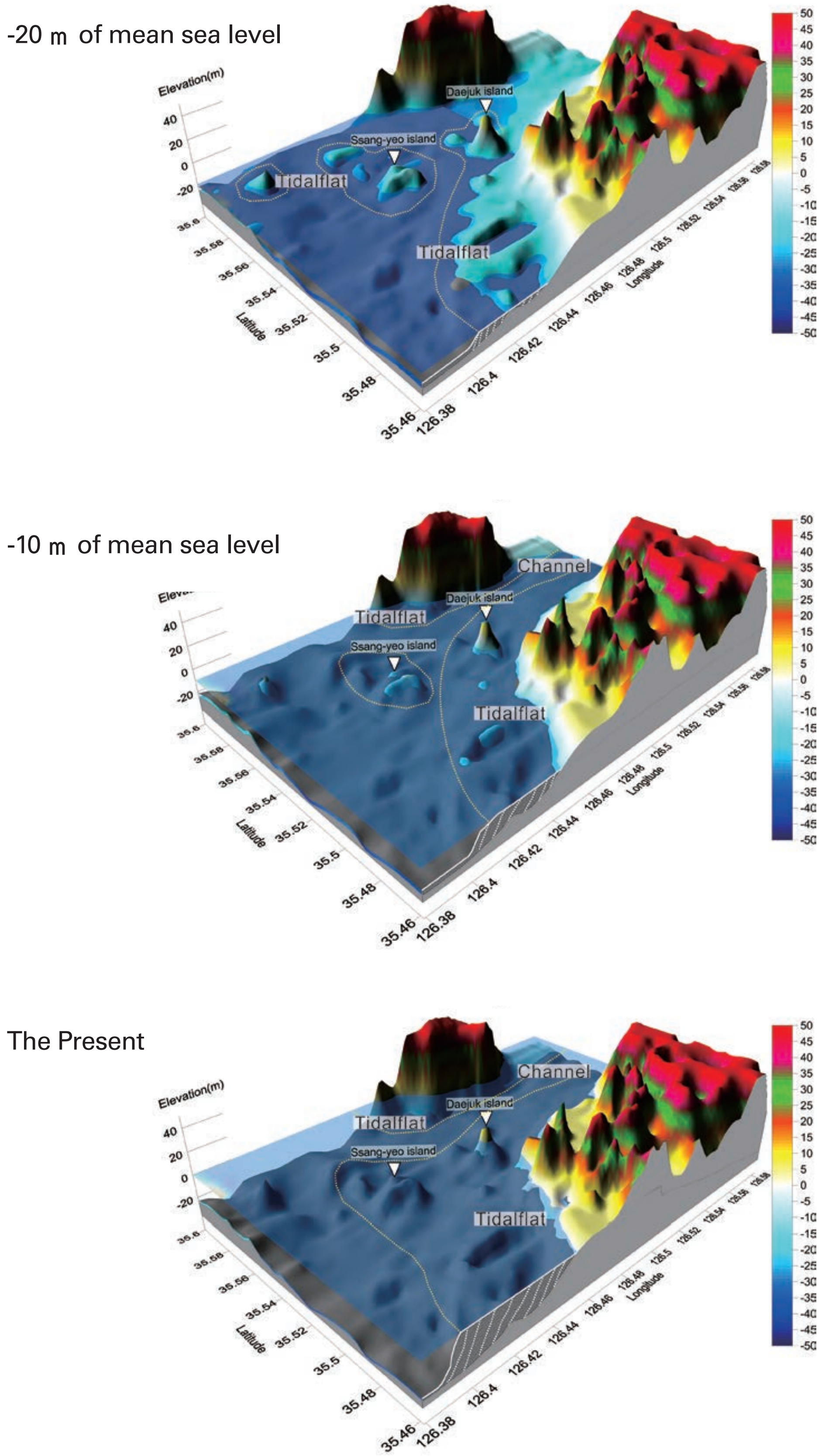


Figure 2-47. Paleo-bathymetry based on acoustic basement in Gochang Getbol showing the formation of tidal-flat sequences and some islands covered by tidal flats according to sea levels of -20 ㎧, -10 ㎧ and the present

Characteristic Tidal-flat Sedimentary Bodies

A chenier, independently formed by sandy and gravel sediments, is observed on mud flat in the upper-intertidal part of Gochang Getbol. The chenier moved toward the land at the speed of 4-23 m/yr from 1989 to 2016. But, more recently, the speed declined dramatically and now the chenier seems to be at standstill. Currently the chenier is about 30-70 m wide and 1 km long. It was much smaller in the past. Not all parts of the chenier are submerged at high tide, but they are located in an area where some parts of them are submerged at maximum high tide. It would be also a nice place for all birds to use it as nesting and resting site because of isolated and protected dry area surrounded by mudflat.

The chenier deposits consist of pebbles, coarse-grained sand and shells. It is 1-3.5 m high, and its shape tends to arch like a bow as it approaches the land. Landward cross stratifications are observed in a cross section. All these characteristics indicate that the chenier is a storm deposit and moves slowly toward the land. Coarse-grained sediments are supplied to the chenier by storms or typhoons at high tide.

In general, multiple overlapped cheniers form a chenier plain. In case of Gochang Getbol, one or two cheniers move and form an independent and characteristic sedimentary body on the mud flat. It appears to be formed due to insufficient supplies of coarse-grained sediments. Several cheniers in Gochang Getbol seem to disappear naturally or artificially.

Figure 2-48. A scenery of outer part in Gochang Getbol showing a curved chenier formed on the uppermost tidal flat. Two islands of Daejukdo (right) and Sojukdo(left) are shown in the upper center.

Individual Components of Sedimentary Sub-environments

Sand flats: Near the bay-mouth a 5 ㎞-wide tidal flat has developed as the outer part of Gochang Getbol. A sand flat about 3 ㎞-wide is present in the lower intertidal area. The width of the sand flat increases in winter and narrows in summer. Mud sedimentary layers are temporarily formed near the lowermost intertidal area, which is located at the lower part of the sand flat. However, those sediments are eroded away seasonally and reveal a sand flat in winter.

Storm deposits, tidal beaches and sand dunes: On the front side of the linear coast in southern Gochang Getbol, a 10 to 20 m wide tidal beach has developed with sand dunes around its landward edge. A sand flat about 500 to 700 m wide also develops along the coast of the tidal beach. This sand flat is an open-coast tidal flat which is directly exposed to the strong waves of the open sea. Therefore, a mud flat is not observed even during summer. During winter, erosion structures such as deep swash bars and hollows and ridges are developed on the sand flat by strong waves, but they are rapidly covered again with sands under lower energy conditions. Sedimentary sequences with hummocky cross or distinct parallel stratification often accumulate. These are upper-flow regime or storm deposits. To prevent damage further inland caused by sands blown in by the wind, local people planted pine trees on the sand dunes in the past. Consequently, the belt of sand dunes became narrow and the dune vegetation was restricted.

Mud and mixed flats: Mud flats in Gochang Getbol are found only in the uppermost part of the tidal flat in the inner bay and rarely develop on the outer part of the bay. Mixed flats are more commonly found, and distributed in a wide area on Gochang Getbol. Both sand and mixed flats there show a seasonal waning and waxing, competing with each other seasonally. A small stream divides the bay into the inner and outer parts. Mud and mixed flats which are not affected by seasonal changes are formed in the inner part. The altitude of the tidal flat surface inside is about one meter higher than that of tidal flats in the outer part. Seasonal changes can be observed only in the outer part.

Rocky substrates: Gochang Getbol has only a few rocky islands that are exposed to tides. As a result, the Getbol has fewer rocky substrates compared to other components of the serial nomination. However, rocky substrates and gravel flats on Daejukdo Island, in the outer part of Gochang Getbol, are exposed to strong waves and tidal currents. This creates dynamic rocky habitats which may be small but are very rich in biodiversity.

Thick Mud-flat Sequences

Most pre-existing former islands on Gochang Getbol have been covered with tidal flat sediments. This causes sand flats in the outer part to prograde inward to the bay. In contrast, seaward progradation of mudflat sedimentary layers, developed by vertical aggradation, is observed in the inner part of the bay. The sand flats and mud flats compete with each other at the middle part of the bay. Wave-dominated sand flats, mixed flats with balanced wave and tidal energies, and tide-dominated mud flats are all well developed from the outer to inner parts of

the bay. Small streams located in the central and bay-head parts cannot play an effective role as an estuary as only small amounts of sediments are supplied from inland. Mud flats formed inside the bay are typical semi-enclosed embayed flats. Gochang Getbol is currently exhibiting a typically transgressing process of an open-coast tidal flat changing to a semi-enclosed tidal flat as it continues to be covered up with sand flats.

The boundary which distinguishes the Pleistocene from Holocene deposits is observed at about 20 m in depth from the tidal flat surface in the outer part of Gochang Getbol. It shows that the formation of the mud flats in the intertidal zone started 8,300 years ago. Gochang Getbol sedimentation rate is about 2.4 ㎜/yr on average which is similar to that of Shinan Getbol. Core data indicates that mud had been deposited rapidly until 6,000 year ago and has slowed since then. Coarsening upward trend is present from about three meters below the surface, indicating that Gochang Getbol changed to open-coast tidal flat at this depth.

With sea level rise, most pre-existing islands were submerged. Compared to Shinan Getbol, the altitude of the coastal land area along Gomsoman Bay is lower with smaller relief. Therefore, tidal flats in the outer part of Gochang Getbol were changed to open-coast tidal flats, transgressing toward the inside of Gomsoman Bay. At present, seasonal sediment movements induced by tides or waves can be observed. This is because islands are no longer able to protect the sediments from hydraulic energy as sea level has become high enough to submerge neighboring islands.

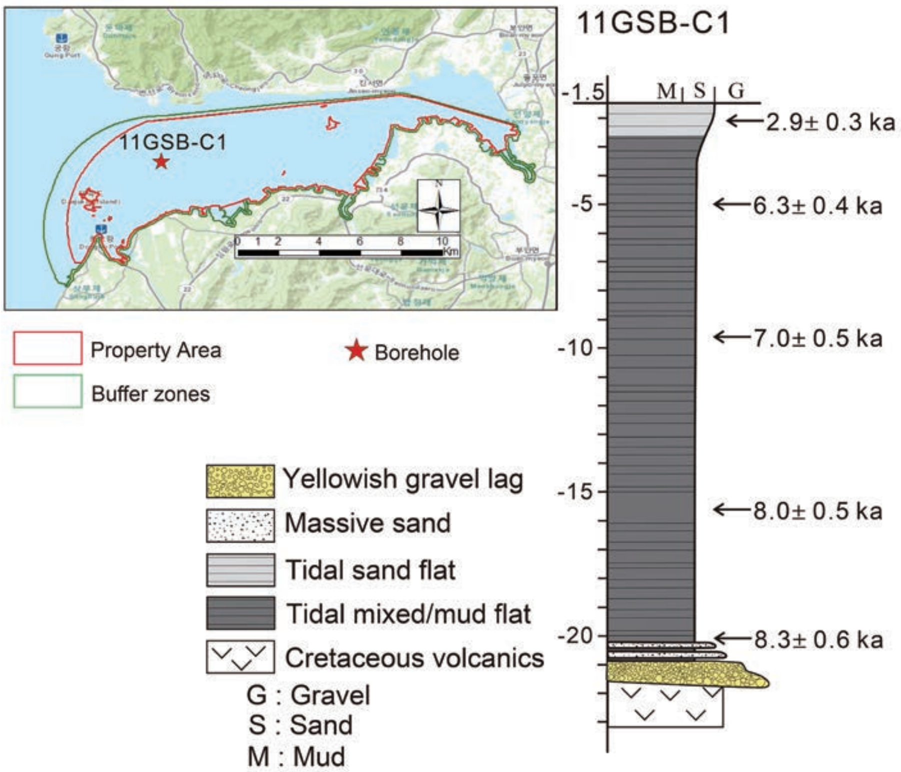


Figure 2-49. Long-core with age data obtained in Gochang Getbol, showing the bottom of the Holocene sequence at -20 m (ca. 8,300 yr BP)

• Biological and Ecological Features

Various Habitats and Community Evolution

Gochang Getbol has a unique ecosystem that is composed of salt marshes, mud flats, mixed flats, sand flats and rocky substrates. A community dominated by Japanese mud crabs and fiddler crabs is observed in mud flats inside the bay. Polychaetes and surf clams are dominant in a community formed in sand flats. In both communities, waterbirds play roles as a keystone species.

In the rocky habitats, a community dominated by starfish, brown turban shell (*Omphalius rusticus*) and filter feeding Pacific oysters is established. Starfish control the ecosystem as a keystone species by predation. The organisms on rocky habitats produce planktonic larvae during their breeding season. These larvae contribute to maintain the food chain as food, and also to stabilize the ecosystem after settlement.

Tide pools of various sizes serve as refuges for those organisms once the rocks are subaerially exposed at low tide. Tide pools closed to subtidal environment serve as a conduit to the coastal ecosystem. A wide variety of communities of macrobenthos, including manicure ghost crabs and milky fiddler crabs, dwell in salt marshes. In particular, milky fiddler crabs are a marine protected species. Those communities enhance the biodiversity of Gochang Getbol. Macrobenthos transfer energy from primary producers to the upper trophic level, thus contributing to the maintenance of a healthy tidal community.

Winter monsoon winds help to mix the sediments, which enables oxygen-rich water to penetrate into the sediments, thereby expanding the aerobic layer. This active bioturbation in mud and sand flats contributes to form an aerobic layer of 6 ㎝ or more, improving the habitat environment and maintaining the density and biodiversity of benthic organisms.

Biodiversity and Endangered Species

Benthic diatoms and primary production

Gochang Getbol hosts 51.7% (194 species) of the whole benthic diatom biodiversity observed in the nominated property. Pennate diatoms including *Diploneis* sp. and *Amphora libyca*, and centric diatoms including *Coscinodiscus* sp. and *Cyclotella stylorum* appear as key dominant species.

The measured value of Chlorophyll-*a*, an indicator showing primary production, ranges from 35.6-67.6 ㎎/㎡ on average. It is noteworthy that the primary production peaks at 215.7 ㎎/㎡ at one site in Gochang Getbol. High primary production of benthic diatoms in turn enables to increase the production of suspension feeders, such as the Manila clams and surf clams. The rocky habitats of Daejukdo Island are rich in these benthic diatoms and marine algae and thus enhance the whole biodiversity in the nominated property.

Macrobenthos

A total of 255 species of macrobenthos is present in Gochang Getbol accounting for 29.9% of the macrobenthos diversity observed in the nominated property. Salt marshes, mud flats and sand flats host 184 species, while 80 species are observed on the rocky habitats. The top two dominating taxa are arthropods (33%) and mollusks (31%) with 84 and 79 species respectively. Sand flats developed on Gochang Getbol have a high density of Manila clams and surf clams, and deposit feeding polychaetes. These organisms are nutrient diets for migratory waterbirds visiting this area. Importantly, tiger crabs (*Orithyia sinica*) [only a single species of this genus has been reported in the world] and lamp shells (*Lingula anatina*) [known as living fossils] are observed in Gochang Getbol.

Tiger crabs inhabiting inside sand flats lay about 54,000 eggs, but only few of them grow into adults. Due to its low density, it is hard to estimate its exact population size and they only live in limited areas. Some local fishermen catch them with traditional indigenous fishing methods.

Figure 2-50. Lamp shell (*Lingula anatina*), living fossil in Gochang Getbol

Lamp shells, which have long and blunt-end tails called peduncles, live within sand flat sediments (Figure 2-50). Their tails are occasionally consumed by humans. Lamp shells are filter feeders that consume benthic diatoms and other species. They enable dissolved oxygen to penetrate into sediments, thus helping to make a favorable environment for other organisms. With a lifespan of about 5 to 8 years, the density of these lamp shells on Gochang Getbol stands at 10-140 individuals/㎡.

Waterbirds

About 41,000 waterbirds from 90 species inhabit Gochang Getbol. This is because Gochang Getbol is rich in large benthic organisms and small potential prey, both of which are eaten by waterbirds. Dominant species include dunlins, great knots, whimbrels and black-tailed gulls.

Endangered species and endemic species

Gochang Getbol hosts as many as 18 waterbird species on the IUCN Red List. Spoon-billed sandpipers, a critically endangered species (CR), are observed in this area as in Yubudo Island. Endangered species (EN) such as great knots, oriental storks, far eastern curlews and spotted greenshanks; vulnerable species (VU) such as Saunders's gull, pochards and Chinese egrets; near-threatened species (NT) including Eurasian oystercatchers, northern lapwings red knots, bar-tailed godwits, red-necked stints and curlew sandpiper are all seen on Gochang Getbol. Importantly, oriental storks (EN) appear only in Gochang Getbol among the serial nominated sites. They visit Gochang Getbol only in winter and feed on Japanese mud crabs and gobies. Oriental storks inhabit the inland wetlands in Mongolia for breeding, fly down to the property in fall to get through winter, and go back to their breeding sites in early spring.

Narrow sand flats are formed in the upper intertidal and supratidal mud flats inside the Gomso tidal flat, where a limited number of milky fiddler crabs are observed in the sand flats. As explained above, many endangered and protected species are observed on Gochang Getbol, and this clearly demonstrates how the habitats in Gochang Getbol are well equipped to feed the observed species while also being protected from various threats by humans.

Figure 2-51. Oriental stork (*Ciconia boyciana*), EN on IUCN Red List, in Gochang Getbol

2.a.vi.3 Shinan Getbol

• Geological and Geomorphological Features

Tidal Channels

At Shinan Getbol there are two large tidal channels that run from north to south (N-S) and eight tidal channels from east to west (E-W). The N-S tidal channels are wide and deep, whereas the E-W tidal channels are narrow and shallow. Of the two N-S tidal channels, the one on the east side has an average width of 5 kilometers and is located between Aphaedo and Amtaedo islands (Figure 2-52). It divides Shinan Getbol into northeast and southwest areas. The other N-S tidal channel on the west side strongly influences the sedimentation processes around the big islands in the southwest part of the archipelago. With a width less than 1 ㎞, the E-W tidal channels are located between the 13 large islands. A wide variety of small tidal channels and tidal gullies is also developed in between the islands with various shapes and irregular distribution.

The depth of tidal channels becomes greater from east to west and from north to south. The wider the tidal channels are, the deeper they are. Some tidal channels with a width of 3-5 ㎞ are deeper than 50 m , but also some channels with a width less than 1 ㎞ are as deep as 20 m . The tidal channels do not show much curvature, but are rather straight. In coastal areas without any tidal flats, bedrock is directly connected to tidal channels. Wide tidal flats show steep slopes at the seaward end of the intertidal zone. They show sometimes a fluctuation of surface topography, which reflects the irregular shape of the rugged bedrock. In the western open-coast part of Shinan Getbol, most islands have steep slopes down to 10 m below sea level, and then are less steep beyond it.

Currents in the tidal channels are variable in flow pattern, depending upon geomorphic characteristics such as distribution/shapes of islands and channel direction/width. The tidal current velocity can at times exceed 200 ㎝/s and in some southern tidal channels can exceed 400 ㎝/s. As for the waves, the height of waves in the inner part is less than 50 ㎝, even when waves in the outer part reach 3-4 m high.

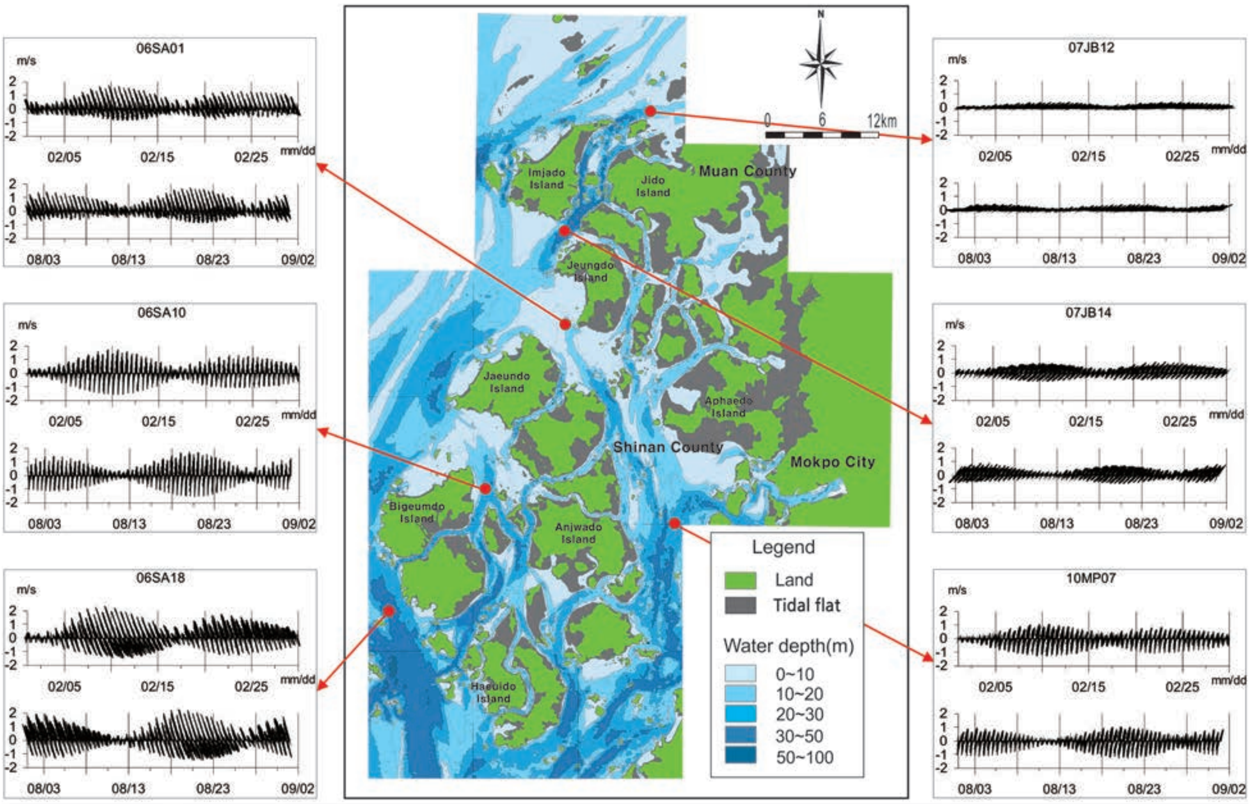


Figure 2-52. Complicated flow directions and velocities of tidal currents in Shinan Getbol

Surface Sediments and Seasonal Changes

The outer part of Shinan Getbol is surrounded by Imjado, Jaeundo, Amtaedo and Bigeumdo islands. On the northwestern or western coasts of these islands, narrow and long sand flats, tidal beaches and sand dunes have formed. In contrast, tidal flats in the east of these islands, that is the inner part of the archipelago, are almost all mud flats. Likewise, all the rocky islands in the inner part are surrounded by mud flats. Narrow sand flats are located on the western coast of the islands facing the open sea. Some of these sand sediments are transported through tidal channels to the inner part, thus forming sand flats in places at the southern and northern corners of islands. Depending on the relative influence of the waves and tidal currents, Shinan Getbol has, in general, developed wave-dominated sand flats in outer parts and tide-dominated mud flats in inner parts (Figure 2-53).

Along the outer coasts of the islands located in the south of Shinan Getbol, sand flats and mixed flats have formed in places. However, mud flats are dominant in both the inner and outer parts of Shinan Getbol, indicating that the waves are less influential than the tidal currents. The characteristics of the surface sediments indicate that Shinan Getbol is affected by the continental monsoon climate typically seen in the eastern part of the Yellow Sea.

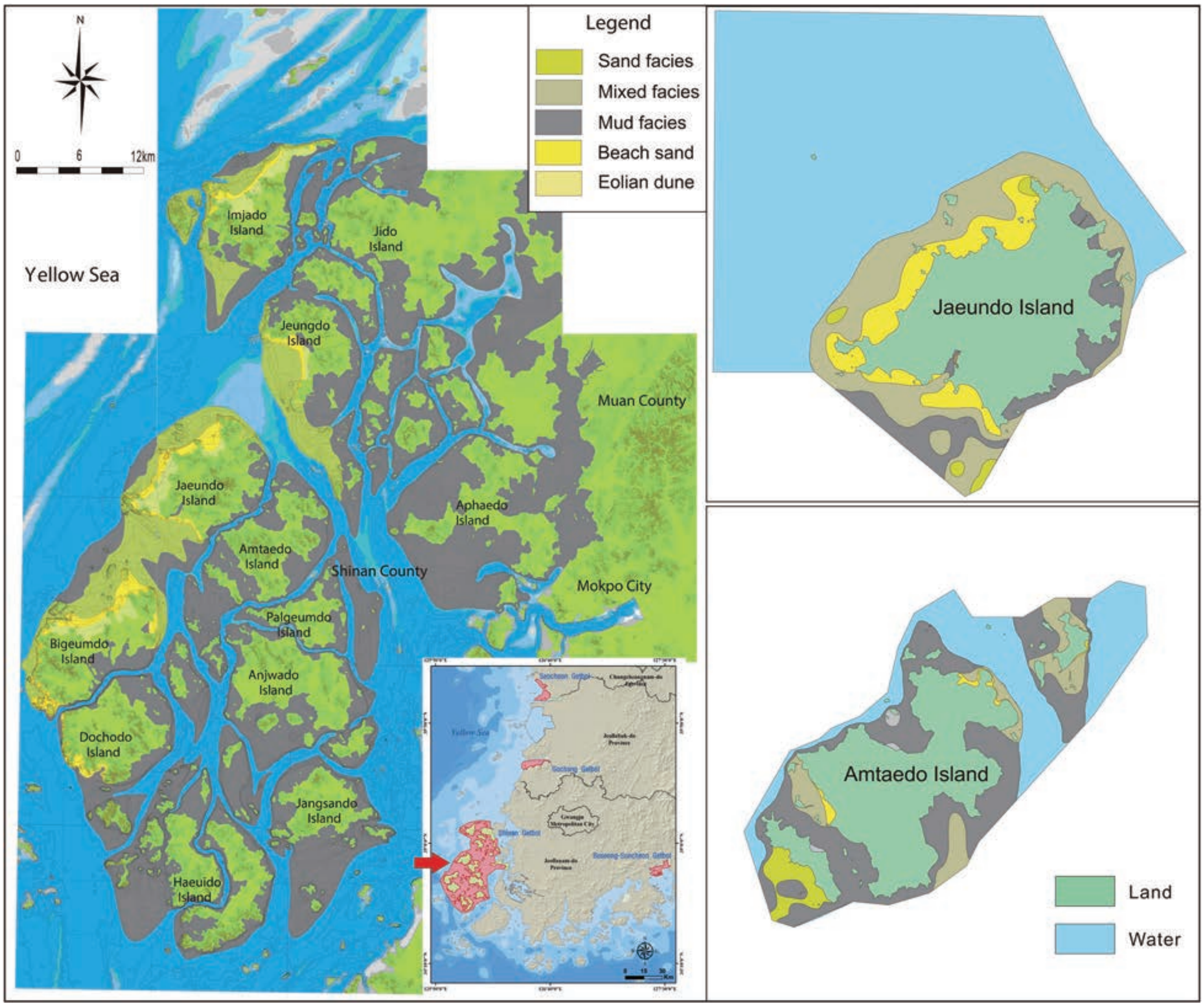


Figure 2-53. Surface sedimentary facies in Shinan Getbol, showing tide-dominated mud-flat facies and wave-dominated sand-flat facies on the inner and outer parts, respectively

Compared to Gochang Getbol, the seasonal changes in the surface sediments are not clearly shown in Shinan Getbol. Sand flats are dominant in both summer and winter in the outer tidal flats of Imjado, Jeungdo, Jaeundo, Bigeumdo and Dochodo islands. In contrast, inner tidal flats consist mainly of mud flats regardless of season. Sand flats in some islands are developed on the southern and northern tips; of them, sand flats that face directly with offshore tend to expand in area or the sediments become a bit coarser in grain size during winter.

Basement Rocks and Holocene Tidal Flat Sequences

In seismic data obtained from the subtidal area of Shinan Getbol, isopach maps indicate that complicated small-scale and shallow tidal channels existed when the sea level was lower than the present. It also implies that Shinan Getbol had a more complex sedimentary system. However, the deep tidal channels we see today have kept their position and dimensions since the Holocene sea level has risen to fill island valleys.

The outer part of Shinan Getbol hosts a Holocene tidal flat and sand dune deposits which are 5-10 m deep. Intertidal deposits with a depth of more than 25 m have developed in the inner part of Shinan Getbol. Based on the depth of tidal channels, tidal sedimentological processes and the movement of the suspended sediments, the Holocene tidal-flats sequence in the inner parts are estimated to be as thick as 40 m in maximum.

Shinan

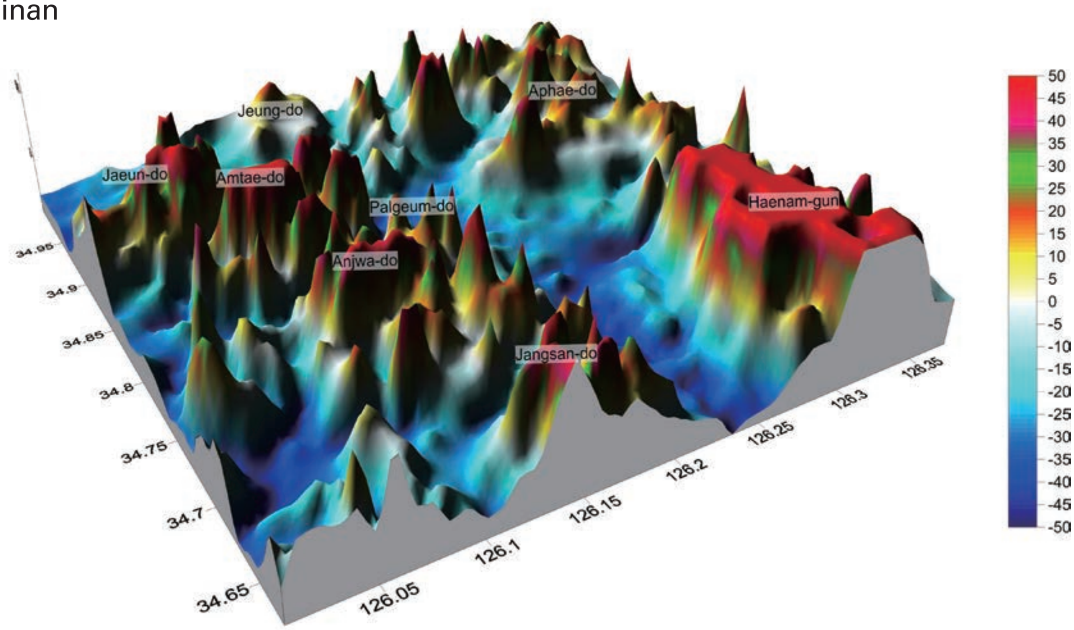


Figure 2-54. Acoustic basement of Shinan Getbol area showing a typical archipelagic environment and much steeper slopes of basement rocks

Characteristic Tidal-flat Sedimentary Bodies

Shinan Getbol displays unique sandy sedimentary bodies developed across the uppermost part of the mud flats. In general, they start from a small island and align in certain directions. The size of these sedimentary bodies varies: they can be longer than 2 ㎞ with a width of 50 m while others may be shorter at less than 100 m in length. Sediments are mainly composed of coarse-grained sand, pebbles and shell fragments. At the upper part of mud flats of open-coast tidal flats, cheniers can be independently formed parallel to the coastlines. However, some sedimentary bodies observed on the uppermost mud flats of Shinan Getbol are different from the typical cheniers. They are narrow and long, developed along the rocky islands, and are formed normal to the coastlines.

Among these characteristic sedimentary bodies observed on mud flats of Shinan Getbol, the one that has developed to the east of the Keunpojakdo Island starts from Galwooseom Island and stretches to the south for 2.5 ㎞ (Figure 2-56). It is very narrow with a width of just 10 m, but at the last 700 m toward the southern end, it widens to 20 to 25 m. Based on the large pebbles and their shapes, they are interpreted as the remnants of typhoon sediments, which were developed, transported and grown by strong typhoons. This kind of the characteristic sedimentary body has not yet been reported worldwide. It is named “sand-gravel string” here.

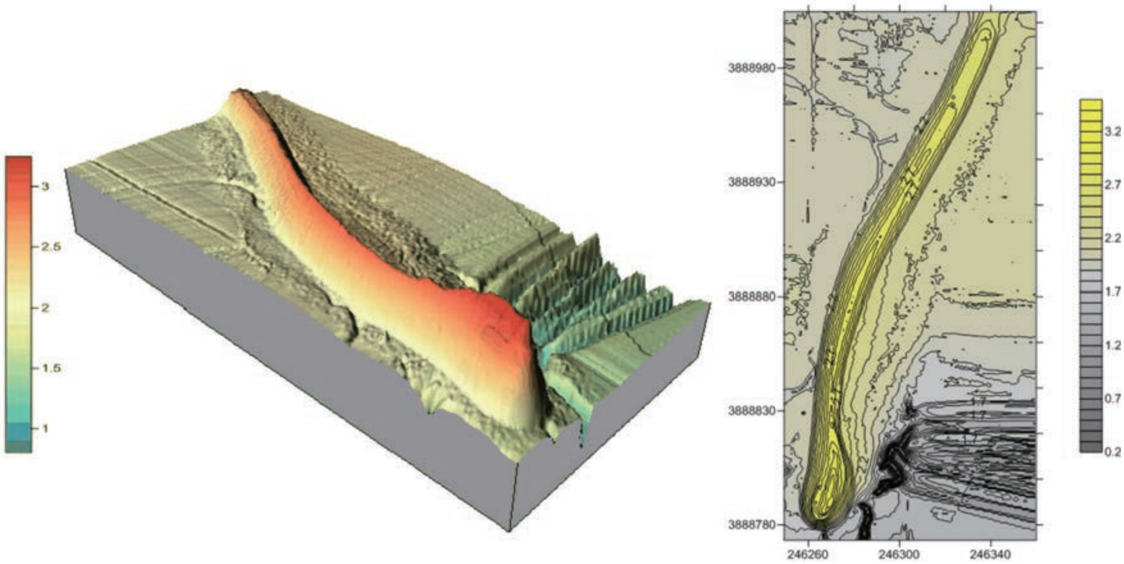


Figure 2-55. 3-D shape of a sand-gravel string developed on Shinan Getbol

Figure 2-56. A picture of a sand-gravel string developed on Shinan Getbol. The second island from left side in Galwooseom Island from which the formation of sand-gravel string seems to be started.

Figure 2-57. A scenery of Shinan Getbol, showing archipelagic feature and tidal channels near Aphaedo and Goido islands

Tidal Gullies

Various complex tidal gully networks have developed on the surface of mud flats in Shinan Getbol. The shape of a tidal gully depends on a number of factors: the slope, sediment type, the supply of suspended sediment, the amount of organic matter included, the dominant direction of tidal currents and the characteristics of adjacent landforms. The tidal channels on sand flats can frequently change, whereas the tidal channels on mud flats see little change because of the cohesiveness of muds. Tidal gullies on mud flats of Shinan Getbol show complex dendritic patterns and vary in shape. In homogeneous sediments, dendritic tidal gullies appear to develop rather randomly. Most tidal gullies on mud flats are not wide, and start from large tidal channels and end in the middle of mud flats. However, in the south of Jido Island and in the west of Aphaedo Island, wide tidal gullies directly connected to the land are present. It appears that these channels start inland, and tidal currents flow back and forth through the widened tidal creeks.

Individual Components of Sedimentary Sub-environments

Mud flats: Mud flats are the most widely distributed sedimentary facies in Shinan Getbol, usually adjoining directly bedrocks or dikes. They exhibit a gentle topographic relief with almost flat slopes toward tidal channels. However, the slopes suddenly become steeper as they come closer to tidal channels. The elevation of the boundary between mud and mixed flats is nearly the same as the local mean sea level. Tidal gullies have developed where mud flats have a gentle slope. Mud flats are mainly composed of silt and clay with less than 20% sand. Due to active bioturbation, horizontal stratification is rarely preserved.

Figure 2-58. Various and complicated patterns of tidal gully networks on the inner mud flats of Shinan Getbol

Sand flats: The coastlines of Imjado, Jeungdo, Jaeundo and Bigeumdo islands face the west coast of ROK. Sand flats are observed mostly in the western coast with some in the southern coastlines of these islands. Sand flats have steeper slopes than mud flats, and sedimentary structures such as ripple marks and swash bars are commonly observed on the surface. The sediments are composed of very fine- to fine-grained, well sorted sand. Most common sedimentary structures include parallel and cross laminations. Massive sand facies are sometimes observed as well. These sedimentary structures have developed under a very strong hydraulic energy regime.

Beaches and aeolian dunes: Beaches and sand dunes are successive sedimentary deposits, because dunes are formed by wind-driven sand from sand flats and tidal beaches. The moving sands are occasionally captured by sand dune vegetation. Sand dunes are commonly observed along the coasts affected by strong wave or wind. On the western coast of Imjado, Jeungdo, Jaeundo and Bigeumdo islands, long and narrow sand dunes are developed from the northeast to southwest. Sand dunes developed in the northwestern coast tend to grow in size southward. The orientation of the sand dune formation is due to the northwesterly winds dominant in winter. Dune marshes formed in low-lying areas of sand dunes are also present behind coastal sand dunes. They are developed where sand dunes block the existing freshwater channels or where the dune swale meets the water table. Sand dunes are mainly composed of very fine-grained sand and can move easily when there is no impermeable layer underneath. The existence of a dune marsh indicates that there is an impermeable layer below the marsh.

Rocky intertidal zones and gravel beaches: Rocky intertidal zones with exposed bedrock occasionally occur along the coast. The zones submerge and emerged repetitively due to the tidal cycle. Depending on lithological characteristics of the bedrocks, the intertidal zones can show distinctive attributes. Gravel eroded from the bedrock may form some gravel beaches.

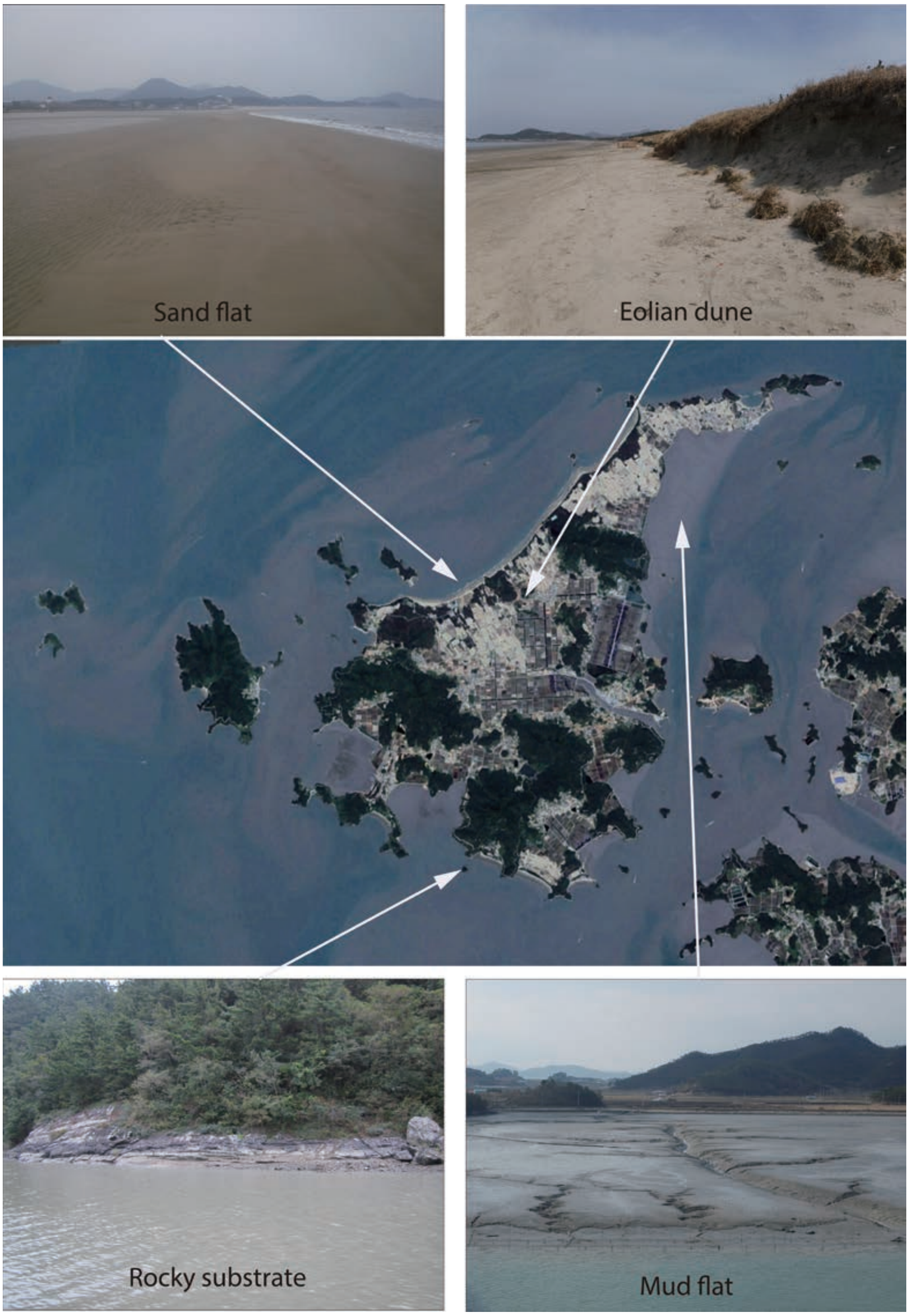


Figure 2-59. Sub-environments formed around a rocky island (Imjado Island) in Shinan Getbol

Thick Mud-flat Sequences

Sand dunes behind the outer islands of Shinan Getbol host sedimentary deposits as thick as 40 ㎧. At the base of the deposits, well rounded gravel lags are present. Above the gravel lag layer, mud facies containing coarse sands and several layers of peat occurs as well as homogeneous mud facies. These layers are tidal deposits formed during the Late Pleistocene Epoch when the sea level was lower than the present. Unconformably above the Pleistocene deposits, Holocene mud layers, intercalated with sands, have a pattern, 5-10 m in thickness, of coarsening and thickening upwards. The mid-Holocene deposits started to form about 7,000 years ago in this region, and indicates the development of transgressive sedimentary sequences in the outer part of Shinan Getbol. This sequence was deposited during the Holocene sea level rise when transgressive marine sediments encroached inland, but was interrupted by repeated erosional episodes. Here, sand flats, sand beaches and sand dunes were deposited after the Pleistocene intertidal muds were eroded, and led to the formation of the transgressive coastal facies up to 10 m in thickness. The thickness does not exceed 10 m even when sand dunes are included.

Very thick intertidal mudflat sequences have been deposited near the deep tidal channels at the inner part of Shinan Getbol over about the last 8,500 years. These intertidal deposits are as thick as 25 m and were formed by vertical aggradation of suspended sediment, a process that is still ongoing.

Figure 2-60. Various shapes of tidal gullies in the inner part of Shinan Getbol

• Biological and Ecological Features

Various Habitats and Community Evolution

Shinan Getbol features well-developed mud, sand and rocky habitats. Each habitat has distinctive communities which lay the foundation for high biodiversity. The uninhabited islands within the nominated property are rich in biodiversity. In the mud flats, a clear evolution of communities is observed, where the mud octopuses are keystone species.

Biodiversity and Endangered Species

Benthic diatoms and primary production

A total of 224 benthic diatoms are responsible for primary production in Shinan Getbol. Imjado Island hosts 166 species, while Jeungdo Island hosts 102 species. Dominant species include pennate diatoms such as *Achnanthes brevipes* and *Nitzschia apiculata* which are the food sources for benthic organisms. The measured value of Chlorophyll-*a*, an indicator showing primary production, of Imjado and Jeungdo islands ranges from 3.5-185.9 ㎎/㎡ (47.1 ㎎/㎡ on average) and 24.3-74.7 ㎎/㎡ (50.1 ㎎/㎡ on average), respectively.

Rocky habitats of Shinan Getbol are home to 144 marine macroalgae species. These macroalgae are partially responsible for primary production. Among marine algae, laver, fusiforme seaweed, green laver and seaweed fulvescens are edible food resources for the locals. For more than 400 years, laver has been cultured at the lower part of the tidal flats from fall to winter.

Halophytes

Salt marshes are not well developed on Shinan Getbol. Halophytes are observed only at the limited upper part of mud flats. In the nominated property, 54 species of halophytes are seen, and 52 species are present on Shinan Getbol (Figure 2-61). The Imjado Getbol hosts 37 species of halophytes with well-developed communities of sea wheatgrass (*Elymus molli*), common reed and herbaceous seepweed (*Suaeda maritima*). The community of sea wheatgrass prevents erosion of sand, protecting the ecosystem. The Jeungdo Island tidal flat has 38 species, while Hauido Island has 35, and sand dunes at Myeongsasimni on Bigeumdo and Jaeundo islands host 37 species.

Macrobenthos

Shinan Getbol hosts a total of 568 species of macrobenthos with an average density of 594 individuals/㎡, comprising an average biomass of 336.1 g/㎡. In mud flats, polychaetes, Japanese mud crabs, amphipods, littoral spoon clams (*Laternula marilina*) are present (Table 2-13). In contrast, amphipods appear abundantly in sand flats. Mud and sand flats have completely different benthic communities. On rocky habitats, a variety of species are observed in high densities. At the upper part of the rocky habitats, granulated periwinkles and Korean common periwinkles are found. From the middle to lower part, black barnacles, Pacific oysters, Korean common dogwhelks, sea anemones, blood clams, Japanese nerite and needle chitons are present in high densities.

A large number of mud octopuses, which are top predators, are found in the mud flats of Shinan Getbol due to abundant Japanese mud crabs providing them with a rich food supply (Figure 2-63). Tidal flats in Jeungdo area have wide sand flat and are very rich in hard clams and amphipods. Hard clams are a major income source for the local people, and amphipods provide food for waterbirds. At the upper part of the sand flats, Stimpson's ghost crabs, which live in burrows, are present. They facilitate the circulation of organic matter by spitting sand grains out of burrows at low tides after feeding.

Continuous production of hard clams and visits by waterbirds indicate that energy flow is actively taking place. Organic matter is being generated by primary producers and decomposed by microorganisms constantly. In addition, regional specialties such as flathead mullet, blue-spotted mud hopper and gobies, which feed on polychaetes are constantly produced. This is another indicator that the energy circulation functions perfectly in these tidal flats.

Figure 2-61. Marshfire glasswort (*Salicornia europaea*) community in Shinan Getbol

Figure 2-62. An inner mud flat with a small sand spit and ebb-tide road in Jeungdo Island of Shinan Getbol

Table 2-13. Dominant species of macrobenthos present in the Shinan mud flats. The only species higher than 1% in abundance are indicated.

Scientific Name	Common name	Taxon	Mean density (ind/㎡)	%
Heteromastus filiformis	capitellid polychaete	Polychaeta	208±35	32.6
Laternula marilina	littoral spoon clam	Bivalvia	105±54	16.4
Perinereis aibuhitensis	sand worm	Polychaeta	24±5	3.8
Assiminea sp.	assimineid gastropod	Gastropoda	23±18	3.6
Stenothyra edogawensis	stenothyrid gastropod	Gastropoda	19±6	3.0
Aphelochaeta sp.2	cirratulid polychaete	Polychaeta	16±7	2.5
Assiminea japonica	Japanese blackish snail	Gastropoda	11±4	1.7
Ennucula tenuis	nuculid bivalve	Bivalvia	11±3	1.7
Megastomia sp.	pyramidellid gastropod	Gastropoda	10±7	1.6
Theora fragilis	fragile semele	Bivalvia	10±3	1.6
Macrophthalmus japonicus	Japanese mud crab	Decapoda	10±2	1.5

Figure 2-63. School of Japanese mud crab (*Macrophthalmus japonica*) on mud flat habitat in Shinan Getbol

Figure 2-64. Chinese egret (*Egretta eulophotes*), EN on IUCN Red List, in Bigeumdo and Dochodo islands of Shinan Getbol

Waterbirds

More than 54,000 waterbirds from 90 species, including 14 on the IUCN Red List, visit Shinan Getbol for feeding. On Jeungdo tidal flat, 5,460 waterbirds from 53 species are observed; 3,290 waterbirds from 43 species visit the tidal flats on Bigeumdo and Dochodo islands; and 20,440 waterbirds from 63 species appear on Aphaedo Island. Dominant species on the Jeungdo tidal flat include dunlins, Kentish plovers, lesser sand plovers and terek sandpipers. Meanwhile, mallards, cormorants, Kentish plovers and black-tailed gulls are dominant in the tidal flats of Bigeumdo and Dochodo islands. However, since Shinan Getbol is large and hosts different habitats, it is possible that the number of waterbirds and their species could be much higher than has been reported. A large number of waterbirds inhabit Shinan Getbol because of ample amounts of benthic organisms providing food for them.

Figure 2-65. Great knot (*Calidris tenuirostris*), EN on IUCN Red List in Jeungdo Island of Shinan Getbol

Endangered species

Shinan Getbol is large and rich in food for waterbird (Figure 2-64 and 2-65). The tidal flat provides a wide variety of endangered waterbirds with habitats. Eastern curlews and great knots which are on the IUCN Red List as an endangered species (EN) are continuously observed on Shinan Getbol. Vulnerable species (VU) including pochards, Chinese egrets and Saunders's gulls are also present. Furthermore, nine near-threatened (NT) species including falcated ducks, red-necked stints, and bar- tailed godwits appear as well.

2.a.vi.4 Boseong-Suncheon Getbol

• Geological and Geomorphological Features

Tidal Channels

Boseong-Suncheon Getbol is developed around Jangdo Island in the northern part of Yeojaman Bay. It also consists of the small estuarine tidal flat in the uppermost bay-head area influenced by two small streams from Boseong County and Suncheon City. Main tidal channels flow from north to south in the east and west of tidal flats of Jangdo Island. Water flows into the channels at average speeds of 54 ㎝/s at ebb tide and 63 ㎝/s at spring tide, the flow becoming a little faster during ebb tide. The topographic relief of the whole tidal flats is relatively very flat with a seawards slope gradient of 0.0007-0.002 degrees.

Surface Sediments and Seasonal Changes

The tidal flats surrounding Jangdo Island are mostly composed of very fine muds. Sand sediments are less than 2% on average. Some suspended sediments supplied from Geumgang and Yeongsangang rivers make their way to the Heuksan Mud Belt in the open sea. Only small amounts of sediments are supplied to Boseong-Suncheon Getbol through the mouth of the Yeojaman Bay, passing through the South Sea of ROK. In this process, a low energy environment is created inside the bay with a small amount of sediment supplied. This leads to very fine sediments being deposited around these islands.

Even though Boseong-Suncheon Getbol is a typical semi-enclosed tidal flat, general characteristics of an island-type (archipelagic) tidal flat are also found around Jangdo Island. Wave energy on Boseong-Suncheon Getbol is very weak, because the tidal flat is formed deep inside the bay. Thus little seasonal change is observed, compared to the other serial nominated sites. However, in terms of the distribution of surface sediments, there is a slight seasonal change: silt contents in the surrounding areas of the tidal channels increase in summer and decrease in winter. This tidal flat has only one mud facies with a mixture of silt and clay. During summer, silt is dominant near tidal channels, whereas clay is the dominant sediment during winter. Due to concentrated rainfall in summer, sediments supplied from streams after rain flow into the tidal flats, temporarily with higher silt content. During winter, suspended sediments supplied from the open sea and clay transported inside the bay are redistributed and deposited. In other words, Boseong-Suncheon Getbol has been formed not by sorting caused by erosion and transportation, but rather by the supply of sediments alone.

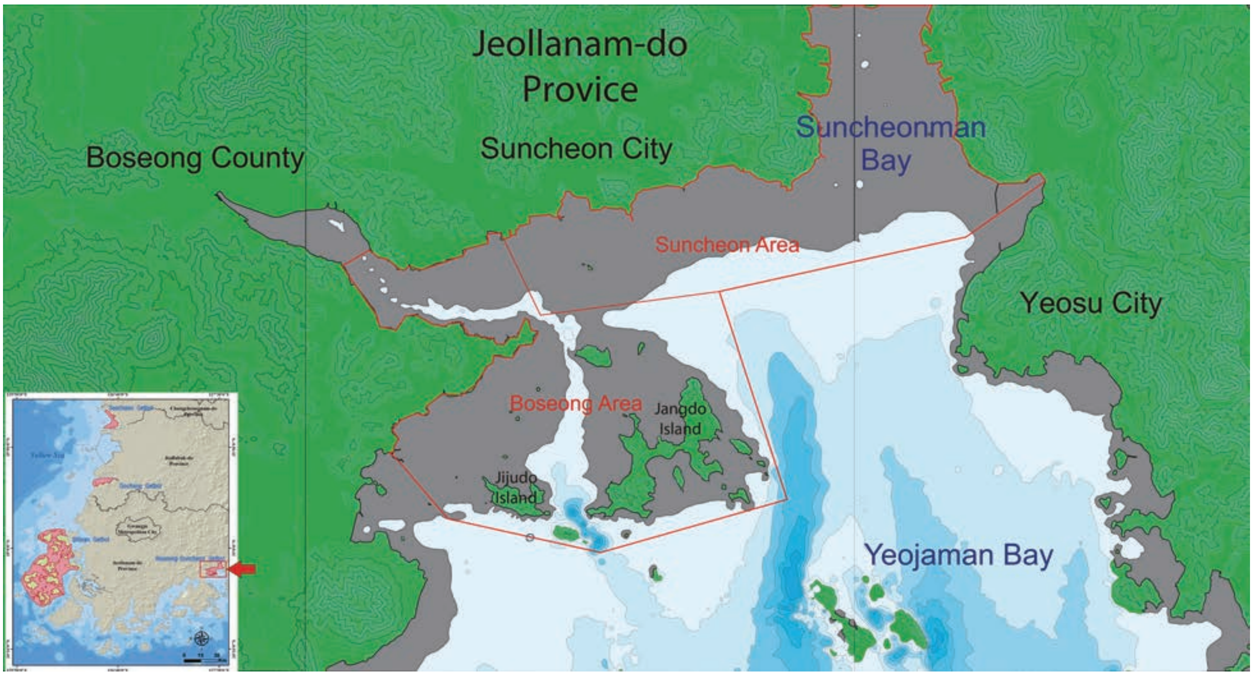


Figure 2-66. Intertidal-flat distribution in Boseong-Suncheon Getbol in which the surface sediments of tidal flat consist only of mud-flat facies

Basement Rocks and Holocene Sequence

Based on paleo-bathymetry, even when sea level was lower than the present, Boseong-Suncheon Getbol appears to have been almost the same as it is today (Figure 2-67). Surface sedimentary facies are all mud facies and do not show a clear vertical evolution pattern. Judging by the overall characteristics, Boseong-Suncheon Getbol has been formed due to vertical aggradation caused by sea level rise. However, the sedimentation rates seem to have been lower than that of other serial nominated sites.

Boseong-Suncheon Getbol does not have enough supply of sediments and thus is in the early stage of the mud-flat formation in the archipelagic tidal-flat setting. Thick mud sediments are deposited near the small estuary situated in the northeast of the property. The mud-flat sequence shows 4 m or more in thickness near the estuary. It is expected, however, that some tidal flats might have much thicker sedimentary deposits.

-10 ㎜ of mean sea level

The Present

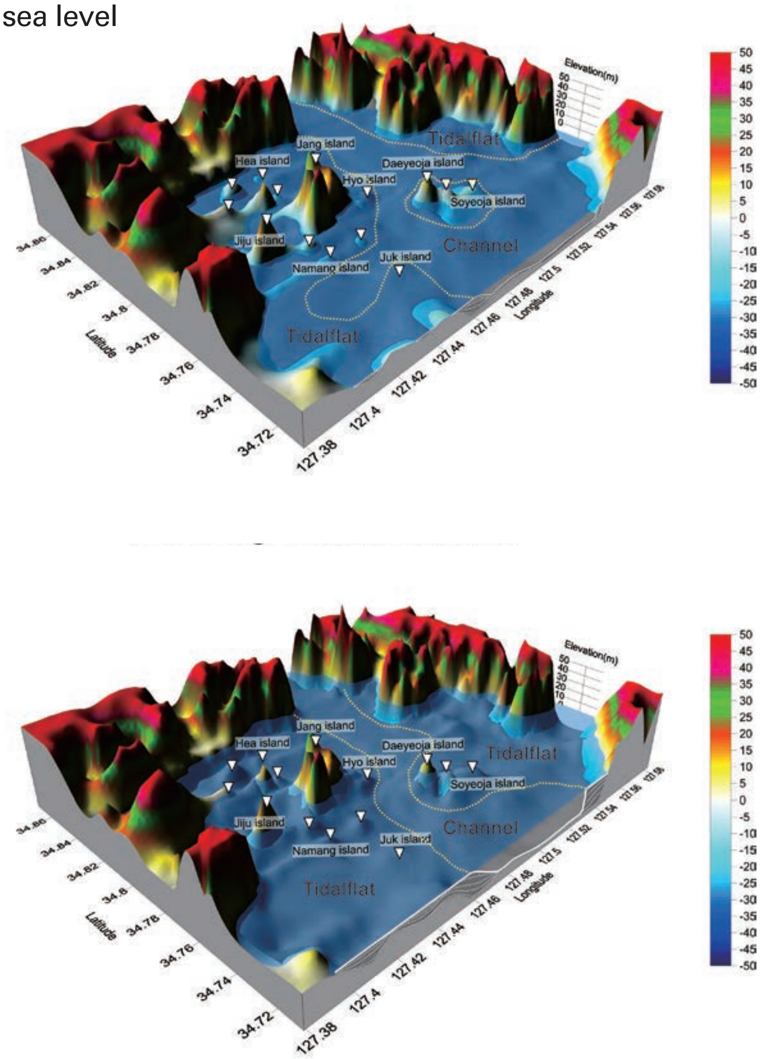


Figure 2-67. Paleo-bathymetry based on acoustic basement in Boseong-Suncheon Getbol area, showing the formation of tidal-flat sequences according to sea levels of -10 ㎜ and the present

Individual Components of Sedimentary Sub-environment

Mud flats: All surface sedimentary facies are mud flats in Boseong-Suncheon Getbol. Compared to the other serial sites, the suspended sediments travel the farthest from their origins to reach this Getbol. This is why Boseong-Suncheon Getbol has finer sediments compared to the other serial nominated sites. Mud flats surrounding Jangdo Island are the most fine-grained tidal flats, displaying characteristics of an enclosed embayed tidal flat as well as island-type tidal flat.

Salt Marshes: The upper tidal flat on Boseong-Suncheon Getbol hostes the largest salt marsh communities in the nominated property. Halophytes including sea-blites (*Suaeda*

asparagoides), broad-leaf phaceluruses (*Phacelurus latifolius*), Gmelin's saltbushes (*Atriplex gmelinii*), seaside lawngrass (*Zoysia sinica*), and square-stem statices (*Limonium tetragonum*) are present, but common reed (*Phragmites communis*) and East Asian seepweed (*Suaeda japonica*) are dominant. The size of common reed community in the nominated property is 110 ㏊ as of 2009 (Figure 2-70). A community where East Asian seepweeds are dominant is as large as 25 ㏊. The sizes of salt marshes are slowly growing. Reed marshes are observed in the mud flats that are 1.1-1.8 ｍ higher than the average sea level, whereas the East Asian seepweed wetlands are observed in the mud flats that are 0.7-1.3 ｍ higher.

Figure 2-68. Tidal gullies and salt marshes in Boseong-Suncheon Getbol

• Biological and Ecological Features

Various Habitat and Community Evolution

Boseong-Suncheon Getbol has well-developed mud flats and rocky habitats around Jangdo Island, but it does not have any sand flats. This leads to relatively poor diversity of habitats, compared to the other nominated sites. However, Boseong-Suncheon Getbol is a good example of an ecosystem where rocky substrates are linked to a muddy substrate. Salt marshes comprised of communities of 24 species of halophytes including common reeds as a main species.

Figure 2-69. Salt marsh and common reed community in Suncheon area

Salt marshes play an important role for producing organic matter and providing habitats. A wide variety of tidal flat organisms inhabit salt marshes hiding from their predators. Also salt marshes limit temperature rise and prevent the organisms' bodies from drying out. Salt marshes have remained stable due to freshwater inflow from land. Therefore, salt marshes provide a variety of living organisms with healthy habitats: a) they provide stable habitats for protected marine species including macrobenthos, red mittens sesarmid crab, convexed crabs, Chinese midas-ear snails, freshwater neritid snails; and b) they serve as a breeding and resting site for waterbirds as well as a place to hide when terrestrial animals like racoons visit the salt marshes to feed on the tidal flat organisms. A community of Japanese mud crabs is well developed on these mud flats. Keystone species include bar-tailed godwits, Saunders's gulls and mud octopuses. Deposit feeders including Japanese mud crabs, manicure ghost crabs, three-spined shore crabs and polychaetes provide the mud flats with an ample amount of oxygen through bioturbation during their feeding and burrowing activities. As a result, about 10 ㎝-deep aerobic layer is created. Uninhabited islands surrounding Jangdo Island have a well-developed rocky ecosystem.

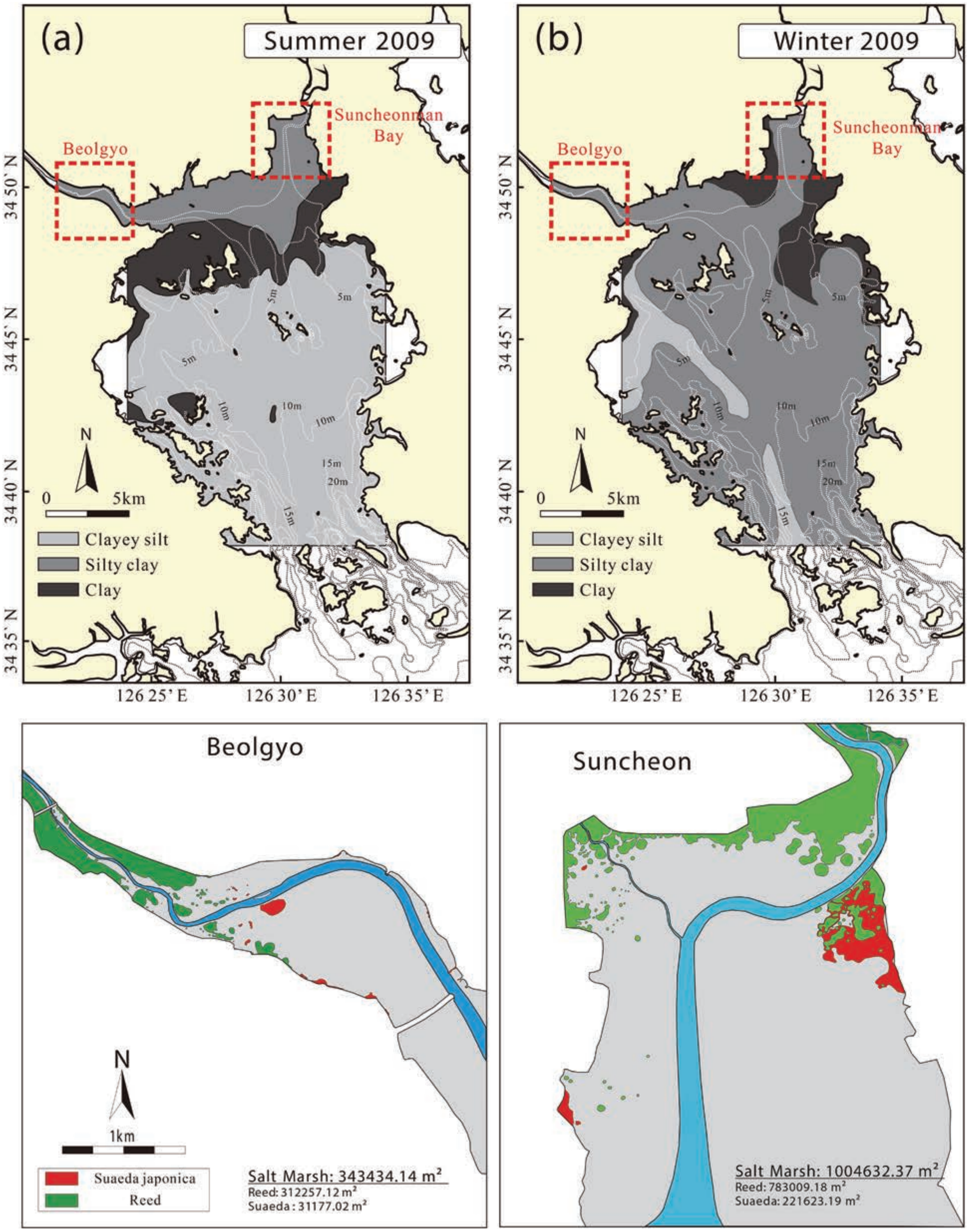


Figure 2-70. Seasonal distribution of surface sediments and salt marshes in Yeojaman Bay

Biodiversity and Endangered Species

Benthic diatoms and primary production

A total of 188 species of benthic diatoms or 50.1% of the biodiversity of benthic diatoms are present in Boseong-Suncheon Getbol. The measured value of Chlorophyll-*a*, an indicator showing primary production, ranges 35.9-66.8 ㎎/㎡ on average. The primary production supports a high secondary production of macrobenthos including filter feeding clams and deposit feeding Japanese mud crabs. Dominant species are pennate diatoms like *Frustulia vulgaris* and *Pleurosigma* sp. and centric diatoms like *Thalassiosira eccentrica*. They account for most of the primary production.

Macrobenthos

Boseong-Suncheon Getbol hosts 445 macrobenthos species. The average density is 2,109 individuals/㎡ and the average biomass is 395.4 g/㎡. Those species become excellent food sources for the waterbirds visiting Boseong-Suncheon Getbol. In particular, there are ample amounts of cockles, which are filter feeders, and deposit feeding Japanese mud crabs, carnivorous blue-spotted mud hoppers in Boseong-Suncheon Getbol. They are all good food sources for visiting waterbirds, as well as protein sources for the local people. Bioturbation by burrowing benthic organisms facilitates the decomposition of organic matters in mud flats.

Waterbirds

Boseong-Suncheon Getbol hosts about 40,000 waterbirds from 99 species. Every year 52 to 73 waterbird species visit, eat and rest on Boseong-Suncheon Getbol. What is notable is that 900 hooded cranes, the flagship species in this region, make their appearance only in Boseong-Suncheon Getbol among the serial nominated sites. In particular, 2,050 hooded cranes visited Boseong-Suncheon Getbol in 2015. Such an increasing trend is the result of the habitat protection activities based on mid- and long-term plans of the Suncheon City.

Endangered species

A total of 19 waterbirds on the IUCN Red List including pochards appear. Most of the pochards (95.8%) visiting the nominated property are seen in Boseong-Suncheon Getbol. Along with hooded cranes, Saunders's gulls, bar-tailed godwits, and other endangered species are seen as well (Figure 2-71). Those endangered species include eastern curlews and black-faced spoonbills. Boseong-Suncheon Getbol provides these endangered waterbirds with the best habitat environment. Boseong-Suncheon Getbol also provides habitats for endangered benethic invertebrates, which only inhabit in limited area (Figure 2-72).

Figure 2-71. Hooded crane (*Grus monacha*), VU on IUCN Red List, in Boseong-Suncheon Getbol

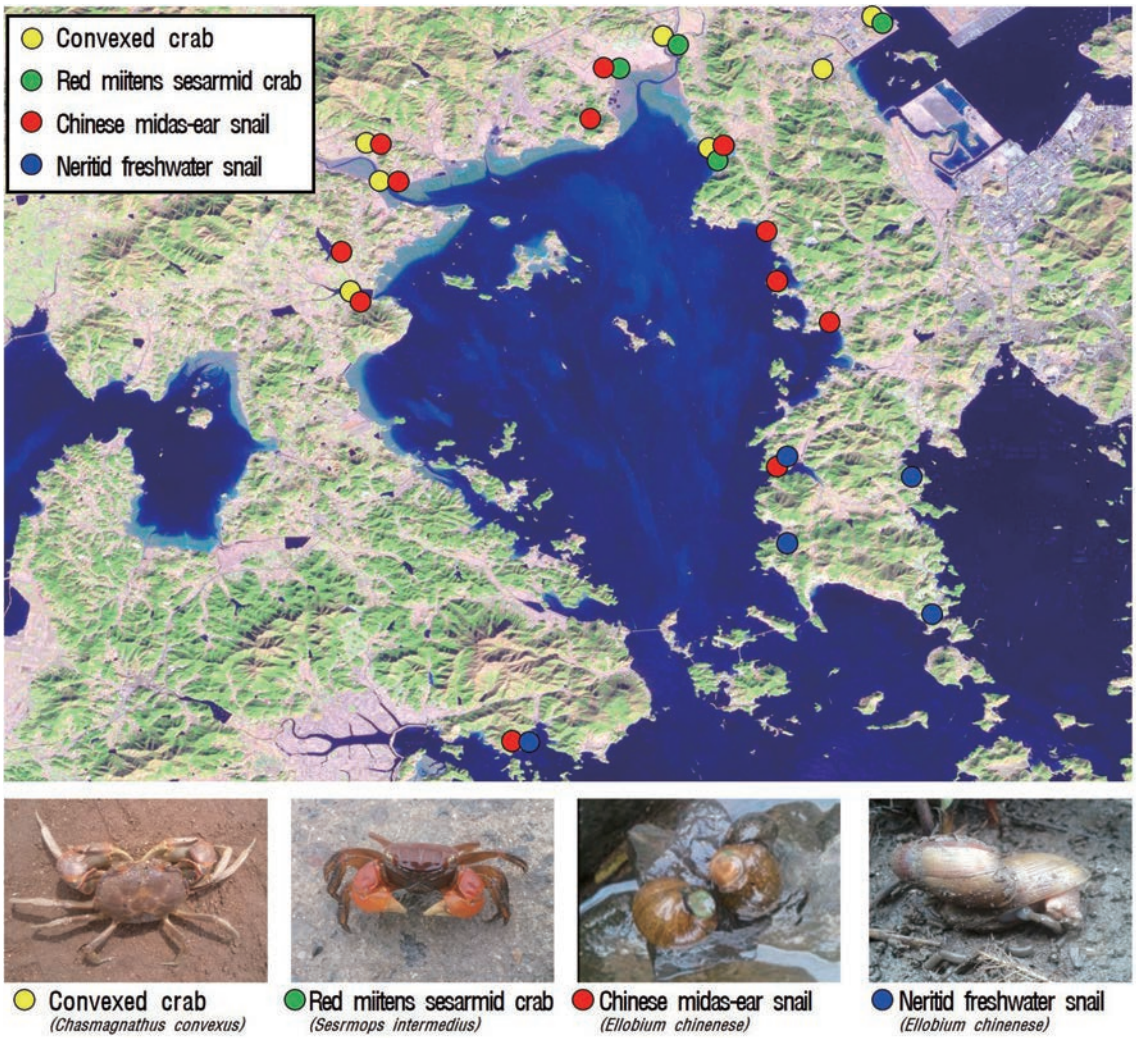


Figure 2-72. Spatial distribution of four endangered benthic invertebrates in Boseong-Suncheon Getbol

2.b History and Development

2.b.i Formation Process of the Nominated Property

During the Cretaceous Period of the Mesozoic Era, the Yellow Sea, unlike today, was occupied by several basins. Thick terrigenous volcaniclastic deposits accumulated in these basins that had been formed by partial rifting and trans-tensional tectonic activity. After several repeated episodes of subsidence and uplift during the Mesozoic, the Yellow Sea came into being in the Miocene about 23-16 million years ago. Marine sedimentary sequences started to accumulate followed by coastal sedimentation after 16 Ma. However, the coastal deposits were only partially preserved due to the sea level fluctuation. A 10-30 ㎙ thick Pleistocene sequence is underlain by weathered rocks along the coasts of the nominated property, which is also overlain unconformably by Holocene tidal-flat sequences.

The history of tidal-flat formation in the nominated property dates back to at least the Late Pleistocene (30,000-125,000 years BP). The boundary between Pleistocene and Holocene sequences in the property occurs at about 5-8 ㎙ below the surface in the sand flat of the outer part and at about 25 ㎙ in the mud flats of the inner part. The uppermost Pleistocene tidal-flat deposits formed around 40,000-50,000 years ago and the overlying Holocene tidal flats started to form around 8,500 years ago. Therefore they show a hiatus of more than 30,000 years. During this interval, the Pleistocene tidal flats were subaerially exposed and were subjected to weathering and erosion. This means that the Pleistocene and Holocene tidal flats have developed through the same processes and that the sedimentation process in the nominated property has continued intermittently over at least the last 125,000 years.

The formation of tidal flats in the property has been controlled mainly by macrotidal range and currents, deep tidal channels, sufficient amounts of suspended sediments as well as continental monsoon climate. About 8,500 years ago, the sea level was 15 to 20 ㎙ lower than the present. At that time, tidal currents ran through deep channels located about 20 to 40 ㎙ lower than the sea surface between numerous islands. Tidal currents carrying large amounts of suspended sediments contributed to forming mud flats between the tidal channels and rocky islands at high tides. As sea level rose, the surface of the mud flats was raised as well, and intertidal mud flats more than 25 ㎙ thick were built up to the present level near the margin of current deep tidal channels. This vertical aggradation is still in ongoing.

As for the inner parts of the tidal flats in the property, the conditions for ecological habitats have been sustained in a very stable manner since max. 8,500 to min. 4,000 years ago. At the early stage of Holocene tidal flat formation, the ecosystem initiated as muds accumulated on basement rocks, which in turn enabled the development of primary producer communities. This eventually led to the emergence of polychaetes, small gastropods, clams and Japanese mud crabs with high biomass as the dominant species. Ultimately carnivore communities evolved, including

mud octopuses (*Octopus minor*) and waterbirds as keynote species. Sand flats in the outer part host communities of suspension-feeding clams, amphipods and polychaetes that feed on organic matter in sand. Waterbirds are the top predators as a keystone species in this community.

The nominated property saw changes in its topography in the modern era due to reclamation. Human activities also affected the supply of sediments and changed the flow of the tidal currents, which in turn led to disturbance in some of the habitats. However, the overall conditions of habitats in the components of the nominated property have all been stabilized.

2.b.ii History of Human Use

In terms of geodiversity and biodiversity, the most significant influences experienced in the nominated property and all other tidal flats in ROK during the Holocene have been human activities since prehistoric times. Historically, the human use of tidal flats has advanced: fishing has evolved from collection to aquaculture, and small-scale reclamation projects have become much larger. The advancement of technology enabled far-off islands to be connected by bridges.

2.b.ii.1 Fisheries

Fishing since prehistory was the first man-made activity to affect the property. Fishing on tidal flats was one of essential elements for the survival of humans living on the Korean Peninsula. Local people have utilized fish, bivalves and marine macroalgae for food. Traces of human activities in the property are found in shell middens left from the Neolithic Period. Those middens are concentrated on the south and west coasts of the Korean Peninsula. Some shell middens from the Neolithic Period have been discovered in the buffer zone of Shinan Getbol.

Fishing in the property began with simple harvesting on tidal flats. It evolved to simple tool-using methods, including the use of hoes and stone walls, building tidal weirs and traps. However, their influence on the ecosystem was negligible. It eventually evolved to fishermen directly catching marine products and sowing seed clams. Even today, as aquaculture is a widely used practice, the local fishermen still utilize conventional tools and hand methods that do not affect severely the topography of tidal flats or ecosystem.

Currently, all of ROK's tidal flats, including the nominated property, are designated as public waters. They are managed under an integrated control system developed by the Ministry of Oceans and Fisheries and are also subject to the voluntary rules and management applied by the locals. A fishing village cooperative consists of several village units, and the member units comply with the same rules. In general, the villagers practice collective fishing. Local villagers

harvest a wide variety of marine products inhabiting the tidal flats, whilst also seeding and growing various marine products including Manila clam, Pacific oysters and laver, in a similar way to farmers planting seeds in the field. This explains the local term 'tidal-flats fields' ('Getbat' in Korean). Collective fishing is allowed only on approved tidal flats. Basically, tidal flats cannot be privately owned or traded and only the local residents are allowed to use the tidal flats. The rules and principles have been long established and practiced. Fishery grounds controlled by village cooperatives in most areas of the property are shared by local residents, and the income generated from the grounds are also equally.

Besides, fishing only with hands and with simple methods can have a positive influence on the area by supplying oxygen into sediments, just like the tidal flat living organisms that dig into the mud and increase the depth of the aerobic layer. There are also self-imposed regulations regarding the harvesting size and volume of bivalves that can be collected.

Active coastal fishing including aquaculture and hand catches in the property sometimes causes issues such as overfishing. The number of fish species and the amount of harvesting may change depending on season, but they have been largely maintained at a static and sustainable level based on the strong government policy suggested by local fishermen (see Section 4.a).

This fact would not have been possible without the strong commitment of regional communities using the property to restore marine resources and maintain the resilience of tidal flats. The tidal flat ecosystems and communities have been well-preserved, largely owing to fishermen who have followed sustainable fishing methods derived from long experience. It also means that fishing activities have become a sustainable part of overall ecological processes. Community fisheries in the property have become a healthy part of the tidal flat ecosystem for thousands of years, not only in the form of collection of the marine products in the tidal flats, but also as an active measure to enhance the resilience of the tidal flats. They have become a healthy part of the tidal flat ecosystem.

Figure 2-73. Joint harvesting by local residents through fishing village cooperative

2.b.ii.2 Reclamation

The first topographic changes of the property took place as reclamation. Reclamation is a much more intensive way of using the tidal flats than fishing. Rias coasts with wide tidal flats are well developed on the south and west coast of ROK and those areas are suitable for reclamation. Small-scale reclamation projects started from the 4th to 6th century and were widely carried out in the Ganghwado Island area in the 13th century. From the late 15th century, reclamation projects have been conducted on a certain scale to resolve food shortages induced by rising populations. In the late 15th century, reclamation projects were expanded to the Gyeonggi-do Province, Chungcheongnam-do Province and coastal areas in the Jeollanam-do Province. Some projects were extended to the estuaries of rivers and around islands.

ROK's reclamation projects in the modern sense began in the Japanese Colonial Period. After colonizing the Korean Peninsula, Japan reclaimed 55,950 ㏊ of tidal flats from 1924 to 1945 with the aim to mitigate flooding, to solve food supply problems in Japan, and to support the war. According to estimates made in 1987 by the then-Ministry of Construction, reclamation involved about 20% of the total area of tidal flats (280,000 ㏊). Many parts of the tidal flats, including salt marshes on the south and west coast of ROK, were reclaimed during the Japanese Colonial Period with no existing documentation. The artificial constructions, such as embankments built during this period, influenced the flow of tidal currents and caused changes not only in the circulation of sediment in the surrounding area, but also in the characteristics of the tidal flat sediments, the ecosystems and the coastlines. Overall, however, such embankments did not irreversibly change the character of the Getbol and its natural processes.

Until the Wetlands Conservation Act was enacted in 1999, government-led reclamation projects, varying in scale and purpose, took place on the tidal flats to secure farmlands and to build industrial complexes. The Saemangeum reclamation project which started in 1991 had a direct impact on the nominated property. The Saemangeum area includes one of big estuaries, merged by Mankyunggang and Dongjingang rivers, in the Korean Peninsula. It affected the flow of tidal currents and sediment supply in Gochang Getbol as well as in other areas of the west coast of ROK. These changes, in turn, directly resulted in the loss of habitats for many of the marine organisms and the reduction of stopover-sites for the migratory birds. The Saemangeum project is the last and final large scale embankment project. Though the impact on a regional scale has been significant, overall the rest of Getbol has maintained its exceptional natural value.

Other than the Saemangeum project, small-scale reclamation projects took place in the upper areas of the intertidal zone of Gochang, Shinan and Boseong-Suncheon Getbol up until the 1990s. These small-scale projects, however, were mostly carried out to create land for small-scale farmland, saltpans and fish farms. They did not block or alter the flow of the tidal currents. Any changes that were induced by these small-scale projects have now been stabilized and are considered to have had minimal effects on the nominated property.

2.b.ii.3 Other Factors (Economic Use for Multiple Purposes)

Along with fishing and reclamation projects, the economic uses of the tidal flats have had an impact on the topography and biodiversity of the property.

Seocheon Getbol had not experienced any topographical changes until the 1960s. The development of saltpans that began in 1965 led to some reductions in intertidal zones. In 1978, the Gunsan National Industrial Complex was completed in Gunsan City, which is adjacent to Seocheon Getbol. Osikdo Island and its intertidal zones, belonging to the Gunsan City's administrative district, were reclaimed for the construction of an industrial complex and the Gunsan Port. This changed the flow of the tidal currents in the area surrounding Yubudo Island. It is also assumed that biodiversity has declined a little by the introduction of sediments and the change of nutrition since the completion of Geumgang River Estuary Bank in 1990.

Gochang Getbol also had no topographical changes until the 1950s. Since then reclamation projects have been carried out to develop farmlands. Saltpans were created in the 1960s and cage aquaculture for fish farms was introduced in the 1990s. Due to these reclamation projects and changes, natural coastlines were artificially transformed. In addition, the Saemangeum Reclamation Project was conducted in the 1990s near Gochang Getbol. After the project, the flow of tidal currents, grain sizes as well as characteristics of marine habitats are confirmed to have been altered, leading to changes in species composition, distribution patterns and fish catch (reduced) in this tidal flat.

Composed of small bays and capes, in various shapes and sizes, Shinan Getbol has a very complex coastline. In 1917, a reclamation project for tidal flats of 682.27 ㏊ was carried out for the first time on Anjwado Island to create farmlands and saltpans. During 1930s to 1950s, a number of reclamation projects and dike construction works were carried out. Small-scale reclamation projects to form farmlands around islands were also conducted, but they had little impact on the natural values of the property.

To improve the mobility of people living on the islands, a total of 15 ebb-tide roads (stepping-stone bridges only exposed during low tides) were constructed with a total length of 10.7 ㎞ in Shinan Getbol. The ebb-tide roads that had been in place for a long time were repaired during the 1990s. All of the roads had built-in measures to allow the sea waters to pass through them. However, it was found that some parts of the bridges impeded too much the flow of tidal currents and sediments supply in the islands. Since 2010, the Ministry of Oceans and Fisheries has conducted an emergency survey on the stepping-stone bridges that were blocking the flow of sea waters and has been carrying out tidal flats restoration projects to widen passage ways for sea water.

After the completion of the Yeongsangang River Estuary Bank in 1991, it is assumed that the biodiversity and population declined slightly as the supply of nutrients from the upper streams also decreased. Other large-scale artificial constructions that are in use to-date are the seven land-to-island bridges and island-to-island bridges in Shinan County. Three additional island-to-island bridges are under construction, but they are built as island-connecting bridges and therefore will not impact the flow of sea water.

Table 2-14. Status of ebb-tide roads on islands in Shinan County

Place	Name	Length (m)	Width (m)	Seawater Circulation
Jido Island	Sopojak-Daepojak	260.0	3.0	Yes
Jeungdo Island	Hwado	1,200.0	3.5	Yes
	Shinchu	260.0	4.0	Yes
	Daegijeom	1,050.0	3.5	Yes
	Sogijeom	220.0	3.5	Yes
	Soak 1	500.0	3.5	Yes
	Soak 2	250.0	4.0	Yes
Bigeumdo Island	Sangsuchi-Suchi	1,000.0	3.0	Yes
Anjwado Island	Buso	520.0	4.0	Yes
	Sachi	260.0	3.0	Yes
Palgeumdo Island	Maedo	400.0	3.5	Yes
	Geosa	300.0	3.0	Yes
Amtaedo Island	Chupo	1,060.0	7.2	Yes
Aphaedo Island	Maehwa-Hwangma	1,500.0	3.0	Yes
	Hwangma-Masan	270.0	4.0	Yes

Boseong-Suncheon Getbol has also been affected by reclamation activities. In the 1980s, the upper parts of the intertidal zones in the north of Yeojaman Bay, Suncheonman Bay were reclaimed to create farmlands. Even though the reclaimed areas account for only a small portion of the entire area of the Yeojaman Bay, the loss of salt marshes was inevitable.

As described above, reclamation, dike construction, change in streams, the establishment of ports and industrial complexes and habitats destruction all are judged to have affected the biodiversity of the property. However, the nominated property is now under multiple layers of legal protection and management, including the Wetlands Conservation Act. Thus, the nominated property is now under a stable management condition with no artificial influence with regards to geology, geomorphology and biodiversity.

2.b.iii Changes in Tidal Flat Conservation Policies

The Saemangeum Reclamation Project (SRP) has had the greatest impact on the geology, geomorphology and biodiversity in the property. Of the government-led reclamation projects since the 1970s, the SRP, which began in 1991, has affected the supply of sediments and the biodiversity of the Gochang Getbol and partly Shinan Getbol of the nominated property.

Waterbirds used to visit the Saemangeum as a stopover site. However, the SRP deprived them of their habitat. The loss of habitats affected fishery production along the entire west coast of ROK. As the number of species and abundance of macrobenthos declined, the biodiversity of migratory waterbirds that visited the area also decreased. On the other hand, Seocheon Getbol and Gochang Getbol, which are adjacent to the Saemangeum tidal flats gained significance as substitute stopover sites, and saw a temporary increase in the number of species and population of birds that flew in.

Large-scale reclamation projects including the SRP have also stirred national controversy, particularly over the Shihwa, Hwaseong and Saemangeum regions in the 1990s. Those controversies also helped raise public awareness concerning the need for various values and conservation of the tidal flats.

Since the establishment of the Ministry of Oceans and Fisheries in 1996 having the purpose of supervising sustainable fishing industry and wise marine conservation, systematic management of public waters reclamation projects commenced. Enacted in 1999, the Wetlands Conservation Act laid a legal foundation for control of reclamation projects and preservation of tidal flats. As a result, by sweeping changes, the second public waters reclamation plan was established in 2001, allowing reclamation in only in 186 regions, covering 3,820 ㏊. A second plan allowed only 2.7% of the 140,300 ㏊ that had originally been approved for reclamation in the first plan.

Since the mid-1990s, environmental protection agencies and academia have continued to raise issues related to the Saemangeum Reclamation Project. This led to increased public awareness about the importance of tidal flats and marine ecosystems as well as the need for their conservation, and eventually strong public support developed in ROK’s population against the reclamation projects. Amid such changes, a dramatic turn in policy was made possible.

Eventually, a phase IV Reclamation Project for Shinan Getbol with a size of 39,000 ㏊ near Yeongsangang River was annulled in 1998. In addition, a reclamation project for Janghang National Industrial Complex with a size of 1,250 ㏊ in Seocheon Getbol was also cancelled. Recognition of the importance of Seocheon Getbol and Gochang Getbol as stopover sites for migratory birds has been growing ever since the Saemangeum Reclamation Project was initiated. Multiple small-scale reclamation projects to create farmland and saltpans have been conducted

in Shinan Getbol as well in the past. However, strong tidal flat conservation policies are now in place at the national and local government level. With the support of these policies, the UNESCO Biosphere Reserve that had been designated in 2009 for parts of the Shinan archipelago area was expanded in 2016 to cover the entire Shinan County. Also, the designation of Wetland Protected Area for parts of Shinan Getbol in 2010 and 2015 were also expanded to cover the entire Shinan Getbol in 2018.

In the past, the upper part of intertidal zones of Boseong-Suncheon Getbol were reclaimed for farmlands. Now, tidal flats near the Suncheonman Bay are protected as a Scenic Spot as well as Boseong tidal flats are protected as a Wetland Protected Area and as a Provincial Park.

No more new large-scale reclamation projects will be allowed in ROK. In 2008 the Republic of Korea government hosted the 'World Wetland Day' ceremony, where the ministers of the Ministry of Oceans and Fisheries and the Ministry of Environment made a joint declaration stating the overall direction of tidal flats conservation policy. The declaration included the following measures: 20% of the coastal wetlands (tidal flats) to be designated as protected areas; to ban large-scale reclamation in principle; to conduct scientific survey on the wetlands; to promote wise and sustainable use of the wetlands; and to actively restore the damage to wetlands.

As a result, ROK's tidal flats, including the nominated property, are all systematically protected by multiple legal measures such as the Wetlands Conservation Act. This prevents any further geomorphological changes or damage to the biodiversity. The Republic of Korea government is also continuing to expand the designation of marine protected areas in its marine ecosystem including the nominated property. Active restoration projects are also being conducted for the damaged tidal flats, backed by further fortified conservation policies. The application being made for World Heritage inscription of the nominated property is an important outcome of these tidal flats conservation policies.